TOPICS OF THE MONTH

Chemical engineering is essential

DESPITE the public utterances of eminent scientists and industrialists on the subject, and the constant efforts of official bodies such as the Institution of Chemical Engineers, the vital importance of having an adequate and well-trained force of chemical engineers in British industry is still not sufficiently recognised.

Industry, which stands to reap the ultimate benefits, must be made aware of the present shortage and must do all it can to help the universities and colleges to make up the deficit. It can do so by endowing new training and research facilities, by giving sympathetic attention to the need for vacation works courses and by making known to its younger workers the opportunities and facilities that exist for practical chemical engineering training. Numerous leading companies have already taken considerable steps in these directions, but there are still too many firms who remain ignorant or apathetic as to what adequate chemical engineering staff might accomplish in their industry.

This ignorance or apathy seems to be confirmed in the Institution of Chemical Engineers' latest report on the supply and distribution of chemical engineers, and indeed the possibility is raised that the failure of some industries to appreciate their chemical engineering needs is the reason why the 1956 Report on Scientific and Engineering Manpower did not give a much larger figure than the 2,200 suggested as the total number of chemical engineers required by 1959. The Institution's own estimates indicate that there is no room for complacency.

To throw further light on the problem, the Institution has made an analysis of its membership which reveals some interesting facts about the industries and occupations in which they were employed in 1957. Thus, in making a comparison with a similar survey carried out in 1953, and making allowance for the more refined methods of analysis used in the 1957 survey, it appears that there has been some increase in the proportion of members employed in administration (1953 = 20%, 1957 = 30%) and a decline in the proportion engaged in plant operation (1953 = 23%, 1957 = 12%).

Compared with the latest known figure for the U.S.A. (31%) the percentage employed on research and development is low (23%), while the percentage employed on design, construction, installation and commissioning is high—21% against 7% in the U.S.A.

In examining the distribution of its members throughout Britain, the Institution finds that the regions with the largest populations of chemical engineers also contain the greatest concentrations of them—concentration being defined as the number of chemical engineers per 1,000 male adults employed. The shortage of chemical engineers cannot be solved by concentration on a few regions.

Turning to the proportions of chemical engineers employed in various industries, it is found that the greatest concentration is in the mineral oil refining industry, which is estimated to have 236 chemical engineers compared with a total number of adult male workers of 32,210, while next come the ' chemical and allied trades ' with 806 chemical engineers amidst 342,430 workers. Further down the list come textiles (56 chemical engineers, 50,790 male workers), the gas industry (60: 121,950), non-ferrous metal manufacture (21: 96,550) and food, drink and tobacco (72: 471,970).

The figures indicate that the mineral oil industry has been more successful than some others in building up an adequate corps of chemical engineers. It is also interesting to note that the atomic energy industry, for which figures were not given in the 1953 survey, showed the sixth largest number of chemical engineers, with 90 returns from Institution members in atomic energy against 257 in chemical plant manufacture, 189 in mineral oil refining, 124 in heavy inorganic chemicals, 104 in heavy organic chemicals and 104 in fine chemicals and pharmaceuticals, out of a total number of 1,724 returns.

Chemical engineering graduates in industry

WHAT sort of practical training should a chemical engineer receive after he has completed his studies at a university, so that he will be fully competent to take his place in industry ? How should his time be divided up ? Is experience in plant design of more value than experience in operation, or development ? Should he be given guidance in such matters as drawing-office routine, management of personnel, and costs, or left to find his own way ?

These are questions to which a variety of answers might be given by experienced authorities on chemical engineering both in the universities and in industry. Small wonder, then, that some firms, faced with the responsibility of putting chemical engineers through a graduate apprenticeship or training scheme, have been at a loss to devise a satisfactory schedule of employment for the future king-pins of industry. Nor is the situation made any simpler by the fact that firms might need chemical engineers for such different purposes as plant design and fabricating or the operation of a chemical manufacturing process.

The easing of National Service demands on chemical engineering graduates, and the consequent increase in the number of training schemes, has focussed attention on these problems in Britain and the Institution of Chemical Engineers has now prepared, in consultation with the Association of British Chemical Manufacturers and the British Chemical Plant Manufacturers' Association, some recommendations concerning graduate training. There seems little to quarrel with in these recommendations. It is emphasised that the object of these schemes is to continue the training of

the graduate on a fairly broad practical basis in order to show him not only how to apply his academic knowledge but also how chemical engineering is integrated into the structure of industry, with special reference, of course, to the industry he has chosen for his own. It is recommended that the trainee should be given some practical training in process plant fabrication (six months), development (four months), design (seven months) and operation (seven months), the figures being illustrative only of how the two years could be divided up, since the duration of each section of training depends on the business of the employer. Emphasis is placed on drawing the graduate's attention to the importance of costs throughout his training.

The order in which training in the various aspects is given will also vary according to circumstances, and it is not necessary that the total experience in each should be continuous. Process plant fabrication and drawing office training should normally come first, otherwise training may to some extent be interwoven with professional experience. Training in process plant fabrication may be given, in part, in a suitable works training school.

Training may be given in more than one works or company. It may be necessary for some employers to co-operate in the transfer of graduates from one establishment to another for a period, in order to ensure adequate training in all aspects.

Many aspects of plant or shop management, which are as important to the plant designer as to the plant operator, will be new to the graduate. A spell in plant or shop management, in however junior a capacity, will bring the graduate into touch with personnel and trade union problems, the various statutory requirements, and safety, as well as with maintenance, material and energy efficiencies, and costs.

The purpose of training in plant fabrication should be to instil a practical appreciation of the uses and limitations of engineering materials. It is not intended that the chemical engineering graduate should be concerned with the niceties of engineering manufacture but rather that he should gain some working knowledge of the inherent problems of construction—of working, cutting, and joining metal and other materials and of erecting plant.

These recommendations, translated by the companies concerned into a more detailed plan, should do much to help overcome the present difficulties.

Kellogg to sell Mexican sponge iron process

THE new process for the production of sponge iron using hydrocarbons is expected to have a big impact, especially on countries which have large supplies of iron ore but limited resources of iron or limestone. This process, which has now become commercially practicable, makes it possible to create a steel industry using iron ore and either natural gas or petroleum. It is claimed to require a much smaller capital investment than that normally associated with the steel industry and can be built economically on a much smaller scale than conventional steel plants.

An announcement from Kellogg International Corporation reveals that its parent company, the M. W. Kellogg Co. of New York, has been appointed exclusive sales and licensing agent for the process by Fierro Esponja S.A. of Monterrey, Mexico. Fierro Esponja is an affiliate of Hojalata Y Lamina S.A., one of Mexico's principal steel producers, who developed the process with the engineering assistance of M. W. Kellogg. The process has been proven in a plant at Monterrey which has been producing 200 tons of sponge iron per day for several months.

Fierro Esponja has just awarded a contract to M. W. Kellogg for a second plant which will produce 500 tons/day of sponge iron. This plant will embody several design improvements to increase the thermal efficiency of the process. The reducing gas, which is produced in a Kellogg high-pressure steam-reforming furnace, contains 85% hydrogen and carbon monoxide and is sulphur-free. Five reforming furnaces will be installed to supply reducing gas for the new plant.

The actual reduction of the iron ore will be performed in four reactors each holding approximately 105 tons of ore. The plant will be engineered so that the heat content of the reformed gas and the reduced ore are completely utilised. To achieve this unusually high thermal efficiency, after reduction the sponge iron is cooled, which achieves another saving by eliminating the need for special equipment and procedures to handle metals at high temperatures. When ready for discharge from the reactors, the sponge iron can either be sent directly to electric furnaces or can be stored for later shipment to steel plants. Experience has shown that reoxidation of sponge iron is no problem.

Chlorine in Germany

A FEATURE of the annual reports of many German companies is the thoroughness with which industrial and economic conditions are surveyed, and often these reports provide useful pointers to production trends in various industries. A recent example is the annual report of the Feldmühle paper and chemical concern, which includes some comments on the production of chlorine in Western Germany. In 1957 this amounted to almost 520,000 tons, the rate of increase compared with that of 1956 being, at 12%, parallel with the increase in the entire chemical sector in Western Germany. Germany's home industry meets the domestic requirements of chlorine almost completely, chlorine imports during 1957 amounting to only 3,400 tons.

Of the total chlorine production, by far the greater quantity is used in the manufacture of chlorinated hydrocarbons. Ranging second in the consumer groups was the production of other chlorinated organic products and tar dyes. The West German pulp and paper industry as a chlorine consumer holds only seventh place with a share of 5% in the total chlorine consumption. By contrast, it is remarkable that in the U.S.A. 15% of chlorine consumption is for the pulp and paper industry.

Chemicals in Rumania

APART from the extensive oilfields in the Ploesti area of Rumania, which attracted considerable attention from both sides during the war, until recently there has been little evidence of a highly developed chemical industry in that country. The two five-year plans, the second of which ends in 1960, have meant a more efficient exploitation of natural resources and many new plants and factories are being erected and older ones enlarged.

Chemical output is now eight times that of 1938 and 3.2 times that of 1950, the number of products at present being 2,800, rising, it is hoped, to 5,500 by 1960. Carbon black, salt, dyestuffs, pharmaceuticals, paints, varnishes and abrasives are among items being exported and, in fact, Rumania exports 83 different chemical products to over 30 countries.

The alkali industry will benefit from the expansion of the soda factory at Ocna Mures, the capacity of which is planned to reach 200,000 tons p.a. by the end of 1960. Among new plants will be one to produce 150,000 tons of calcined soda annually, and another for 30,000 tons of electrolytic caustic soda and 24,000 tons of chlorine.

At Copsa Mica a plant is being erected to produce 40,000 tons of sulphuric acid p.a. By-products will include 100,000 tons p.a. of superphosphate fertiliser, hexametaphosphate for the oil industry, saltcake for glass manufacture, fuller's earth for the oil and food industries, copper sulphate for the vineyards, and aluminium sulphate for paper manufacture.

For fertiliser manufacture, ammonia is to be produced from methane in a plant at Victoria with an annual capacity of 30,000 tons. By 1960 there will be a 100,000 tons p.a. ammonia plant in Moldavia. This year a new plant comes into operation at Navodari, to supply 170,000 tons of phosphates per year. The production of insecticides, fungicides and herbicides is being increased.

Synthetic organics are being produced on an ever-increasing scale, while the manufacture of detergents is a logical offshoot of the Rumanian petroleum industry. Two new ventures are the production of cellulose from reeds, at the rate of 200,000 tons per year, and synthetic rubber from oil well gases.

Chemical research institutes have been organised at Iasi and Cluj with collectives at Bucharest and Timisoara. In Bucharest is the I.C.E.C.H.I.M. Institute for Chemical Research, in Ploesti there is the Petrochim Institute, while in Medias the Chimigaz Institute is working on methane processing. Methane has been converted by an electric-arc process into acetylene and new techniques have been evolved for the manufacture of aniline, benzene hexachloride, glue, superphosphate, bleaching powder, etc. Pentane yields amyl alcohol, and paraffins can be oxidised to high-grade alcohols and polyvinyl alcohol for plastics. The exploitation of minerals, such as serpentine, dolomite, alluvial sand, etc., is being extensively studied.

Further details of Rumania's chemical industry were contained in an article in CHEMICAL & PROCESS ENGINEERING, 1955, **36** (6), 217.

Monitored production for Russian tyre factory

PROOF of further applications for the new system of plant performance recording developed by the British Iron and Steel Research Association, and originally envisaged as a production aid in the manufacture of steel products, is contained in the news that the system is to be used in a big new Russian tyre factory. In this factory, to be erected near Dneipropetrovsk, the entire process of tyre and tube making is to be monitored hourly. Production figures will be obtained for the number of batches of rubber produced by the internal mixers, the number of yards of fabric, the number of extruded treads or, in the case of giant-tyre manufacture, the number of tread parts, the number of uncured and cured tyres and the number of uncured and cured inner tyres.

Machinery and equipment for the factory are being built and supplied by a consortium of British firms and the contract to date is valued in the region of £12½ million. The system involves the equipment of some 500 ' detection points ' throughout the plant. All the counting equipment will be centralised, and an adjacent office will be equipped with page printers where the hourly production totals will appear coded according to size or type. Additional overriding totals for each shift will also be produced and at these times something like a thousand characters of data will be printed out.

New industry with plenty of bounce

HAILED with joy as Britain's first venture into the large-scale manufacture of general-purpose styrene-butadiene rubber, the bringing into production of the new £6-million plant of the International Synthetic Rubber Co. Ltd., on Southampton Water, turns the final nut in the well-laid plans to make the country independent of overseas supplies of this product. Indeed, with a capacity of 70,000 tons p.a., the plant should make it possible not only to supply all U.K. requirements, but also to export impressive quantities. Raw material supplies have already been nicely attended to with butadiene available from the nearby Fawley refinery of Esso and styrene from Forth Chemicals at Grangemouth, Scotland, and from Shell at Partington, Lancs.

Nice going, too, was the completion of the plant in 16 months, beginning in February 1957, first starting production in March 1958, and reaching full-stream output on July 20. Blaw-Knox Co., of Pittsburg, Pa., U.S.A., took care of the designing, installation and commissioning work, the detail engineering, procurement and mechanical erection being entrusted to a British concern, Matthew Hall.

The plant uses a low-temperature, ' cold,' emulsion polymerisation reaction and, when a predetermined quantity of the monomer charge has been reacted, the polymerisation is short-stopped and the resulting latex passes to the recovery system, where the unreacted butadiene and styrene are removed from the latex. The stripped latex is then blended and oil extender, if required, is added as an emulsion. The next step is the

coagulation of the latex to yield a slurry of rubber in aqueous liquor. This slurry is filtered and washed and the crumb is dried and finally compressed into bales.

British purchase of S.B.R. rubber before the launching of the new Hythe plant was costing more than $25 million p.a. Present figures show that U.K. consumption of natural rubber in 1958 is running 19% above the 1947 level, whereas the consumption of synthetic during the same period has risen 2,240%.

Other units of Britain's new synthetic rubber industry, at present in production, include Dunlop's £600,000 experimental styrene-butadiene plant at Fort Dunlop, Birmingham; Monsanto's high-styrene-butadiene copolymers plant at Newport, Mon.; I.C.I.'s production of butadiene polymers at Wilton; British Geon's nitrile rubber plant at Barry, Glamorganshire; while I.C.I. and Albright & Wilson are producing silicone rubbers and du Pont are progressing with their *Neoprene* project in Northern Ireland.

'Terylene's' American cousin

A POLYESTER fibre that is chemically the same as *Terylene* is to be made in the U.S.A. by a new company formed by Imperial Chemical Industries Ltd. and Celanese Corporation of America, who will have equal shareholdings. The location of the plant to manufacture the fibre has not yet been decided; the plant is expected, however, to have an eventual capacity of 40 million lb. p.a. and will manufacture both continuous filament yarn and staple fibre.

The fibre will be marketed by Celanese Corporation on behalf of the new company, under the trade name *Teron*.

I.C.I. now has a plant capacity for *Terylene* of 22 million lb. p.a. and this is being expanded to 30 million by mid-1959. The company has recently announced plans for the construction of another plant which will bring its total *Terylene* capacity in the United Kingdom up to 50 million lb. p.a. The I.C.I. subsidiary in Canada, Canadian Industries Ltd., manufactures *Terylene* in a plant with a capacity of 11 million lb. p.a. I.C.I. has sub-licensed companies in France, Holland, Western Germany, Italy and Japan to manufacture polyester fibre.

New trends in sea-water distillation

DISTILLATION, the traditional process of man as well as of nature, is today still the most practical means for recovering pure water from sea-water. But distillation requires heat and heat costs money. Only where heat is cheap and water has unusually great value is this process likely to be employed on a large scale. One such locality is Kuwait on the Persian Gulf, where huge multiple-effect evaporator plants have now been enlarged by the addition of flash-type units to a capacity of nearly 5 million gal./day to supply the town and the oil refinery with potable water.

Giving this example in a lecture to the American Society for Testing Materials, Dr. E. P. Partridge points out that any process of evaporating sea-water must face not only a big economic obstacle, but also a big technical one—the deposition of scale with its resultant interference with heat transfer. Only by chemical conditioning of the sea-water feed was the original installation of multiple-effect evaporators at Kuwait able to maintain its rated capacity. Scale has been a particularly serious problem for vapour-compression evaporators. These operate with such a small difference in temperature across the heat-transfer surface between the condensing steam and the boiling water that any fouling of the surface materially slows down the process.

A new design of vapour-compression evaporator, the centrifugal-barrier compression still, would seem to have attractive possibilities. This spins the evaporating sea-water on the inside surfaces of a set of flattened, rotating double cones and, by means of a blower, the vapour is taken off to be condensed on the outer surfaces. The heat liberated by the slightly compressed, pure water vapour as it condenses causes the evaporation of the sea-water on the inner surfaces of the spinning barrier. An overall heat-transfer coefficient of at least 2,200 B.Th.U./sq.ft./hr.°F. has been maintained for 200-hr. runs at 125 and 150°F. without any indication of scale formation. At 180°F., however, a scale of calcium carbonate formed rapidly.

A semi-commercial unit now in operation is expected to require only about 42 kwh. per 1,000 gal. of pure water produced. While this is about 17 times the theoretical minimum energy input, it is less than half that of current vapour-compression stills.

Some further comments on sea-water distillation processes appeared in an article in our February issue this year.

Carbon holds its own in extraction metallurgy

THE remarkable role of carbon in the history of extraction metallurgy was the subject of the British Coal Utilisation Research Association's 7th Coal Science Lecture, delivered by Sir Charles Goodeve, O.B.E., D.SC., F.R.S., Director of the British Iron and Steel Research Association. The lecture included a discussion of the chemical engineering and kinetic aspects of reactions in which carbon took part and Sir Charles discussed the problems of bringing the molecules together to react and of separating the products of the reactions. Fortunately, carbon's remarkable reducing properties could be transferred to carbon monoxide, which could penetrate into the pores of ores. Furthermore, carbon could reduce the carbon dioxide generated in the reaction, thus maintaining the reducing power of the gas.

Yet another advantage possessed by carbon was that in its various forms it provided a wide choice of reactivities. The ability to choose the best degree of activity for a particular purpose was of great value, especially in the blast furnace and the preparation of ores for smelting, where the reactivity of the coke was a key factor in the success of the operation.

Sir Charles did not think that carbon's unique position in extraction metallurgy was likely to be seriously challenged within the foreseeable future.

The present state of the theory relating to the mixing of granular solids does not allow of an exact design based on fundamentals. Existing principles can, however, be used to interpret the data from experiments with given materials and apparatus. This can often lead to improvements in existing processes.

Selection of Plant for Mixing Granular Solids

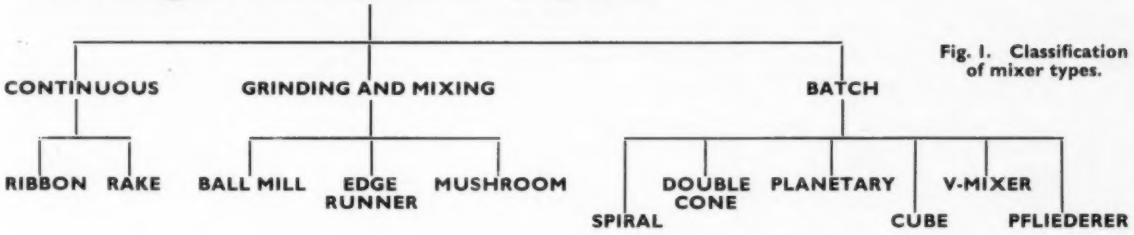

Fig. 1. Classification of mixer types.

By H. Bannister, Ph.D., M.Sc., D.I.C., A.M.I.Chem.E.

THE unit operation of granular solids mixing is widely employed in modern industry, which inherited its practices from very ancient times. Evidence of crude hand-mixing processes used by early Man is available in many museums.

In view of the universality and versatility of the processes it is remarkable that the fundamental aspects have not attracted more attention. Most of the literature describing investigations of a basic nature has arisen since World War 2. This may be due partly to the rather complex nature of the mathematics involved and partly to the success of the 'try it and see' approach which in solids mixing has been more evident than in other unit operations.

Characteristics of various machines

Several mechanisms can be involved in a solids mixing process.[1, 2]

(*a*) *Shear.* Bulk displacement of large volumes of the mix.

(*b*) *Convection.* Small-scale transfer of particles in the mix.

(*c*) *Diffusion.* Displacement of the individual particles within portions of the mass.

(*d*) *Mulling.* Deformation, pressing and smearing of the mix.

(*e*) *Impact.* Scattering of individual particles.

Fig. 2 shows eight typical mixer types, while a further type, the Werner Pfliederer machine, is shown in Fig. 3. The characteristics of all these various types are shown in Table 1 together with an indication of their suitability for various duties. Many others are available, but an understanding of the mechanism of those listed will usually enable an unfamiliar machine to be characterised. Fig. 1 shows one of many possible classifications. Undoubtedly the batch machines form the largest group, since they are flexible and comparatively cheap. It is usual to install several machines for steady production, so that a breakdown of one unit will not completely stop the plant.

Mechanism of the mixing process

In batch machines it is possible to distinguish different mechanisms of mixing which dominate the process for different periods after the start of a mix. Continuous machines display

Table 1. Characteristics of Mixers

Type	*Action*	*Sphere of usefulness*
Spiral	Shearing due to tapering worm	Dry, powdered, free-flowing solids of uniform size and density
Double cone ..	Diffusive mixing	Similar to spiral machine
Cube	High-velocity gradients	Can mix materials which stick or aggregate; not more than 60% of the volume should be filled
V-mixer ..	High-velocity gradients	Can handle materials with a large density difference
Mushroom ..	Tumbling of materials assisted by action of balls shearing mechanism	Mixing pharmaceuticals. There is some grinding action in this mixer.
Planetary ..	Axis of rotating paddles also rotates round stationary pan centre axis	Only suitable for fairly free-flowing materials
Werner Pfliederer	Specially shaped blades shear and knead the materials	Ideal for sticky mixtures. One of the most advanced mechanically
Edge runner ..	Heavy wheels cause a mulling action	Ideal for sticky pastes. Often used in explosives manufacture
Ribbon	Mainly convective mixing	Free-flowing ingredients can be mixed even if they have different sizes and densities. But intimate mixing in which diffusion is needed can be very slow

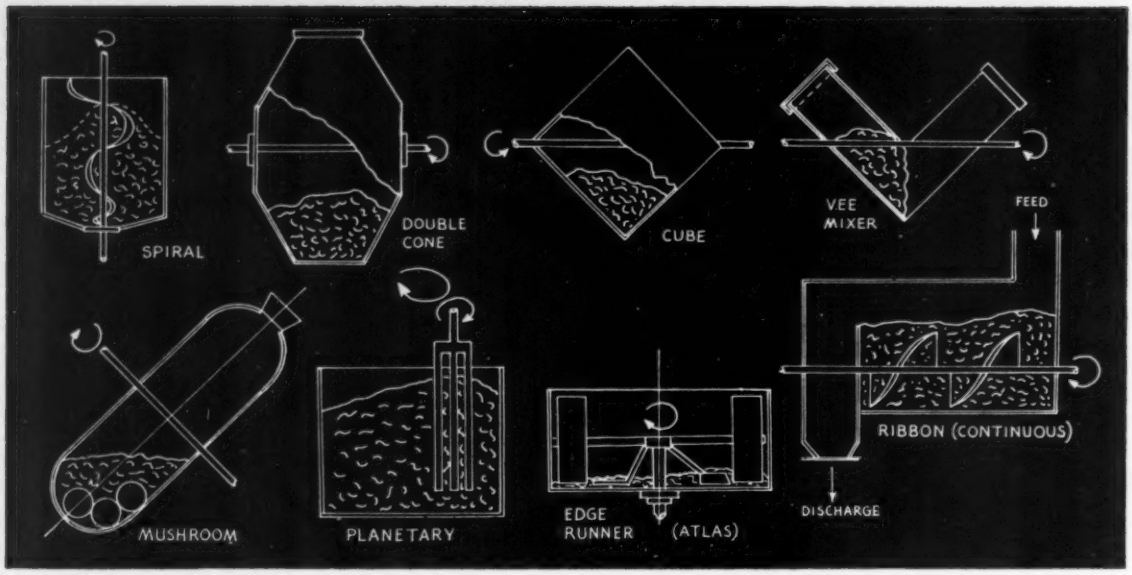

Fig. 2. Diagrammatic sections through eight representative mixer types, a further type being shown in Fig. 3.

similar characteristics, but in this case the modes are present in different zones in the mixing chamber.

Shearing is present at the start of mixing and initially the scale of change is very large. Gradually convection, which is similar to shearing but on a smaller and more localised scale, becomes dominant. Many mixes, particularly where great homogeneity is not required, use only these two forms of movement, since diffusion, the next process in the group, is very slow and lengthens the mixing time. Diffusion is necessary, however, where very intimate mixing is required.

Where ingredients are slightly sticky, mulling may be needed, the motion being typified by that produced in the edge-runner type of mill. Impact is a characteristic of high-speed machines very often associated with grinding and milling of the product.

If a mixing process is continued for too long it is possible for the ingredients to separate.[4] This is particularly true with ingredients of widely differing shape, screen size and density. In general the more alike the components are the more intimate will be the mixing achieved and the shorter will be the mixing time. Also the finer the material the more intimate the mixture if all other factors are constant.[5, 6]

The effect of moisture in powder-mixing processes is complicated, the main effect being to prevent the components from flowing freely. Five classes of mix have been classified on a scale of increasing moisture content:[7]

(1) Pellet-powder state, which forms when a small amount of water is added to visually dry ingredients. The components form balls surrounded by dry material.
(2) Pellet state, where increase in moisture content produces a granular appearance.
(3) A plastic state produced when further addition of water creates a homogeneous mass which is very resistant to shear.
(4) A sticky mastic which adheres to solid surfaces.
(5) A fully liquid condition where the viscosity is controlled by water addition.

The last two conditions can hardly be considered as dry solids mixing and will not be discussed further.

In selecting machines to deal with mixes whose ingredients behave as in (1) a wide choice is available and nearly all the types illustrated in Figs. 2 and 3 can be employed. Condition (2) calls

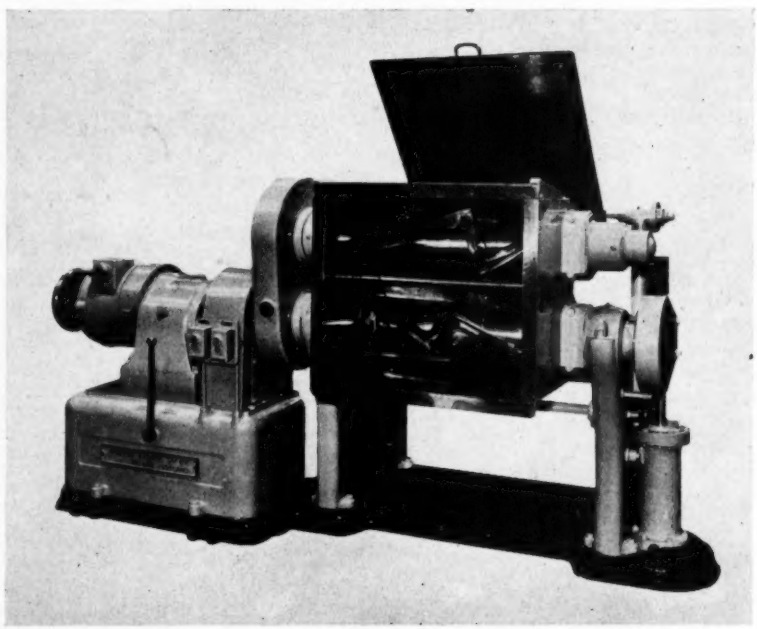

Fig. 3. Pfliederer-type mixer manufactured by Morton Machine Co. Ltd.

for a mulling machine and the field is at once restricted mainly to appliances of the edge-runner type. Condition (3) calls for a Pfliederer type of unit.

Methods of assessing the performance of mixers

So far the only approach to mixing problems which has yielded theories of practical value has relied on tests of existing machines when mixing given ingredients. The converse problem of designing a mixer from first principles to mix ingredients with stated properties has not been successfully tackled as far as the writer is aware.

There have been two main avenues of advance. The first,[8, 9] the statistical method, envisages a mixture in the forms shown in Fig. 4. In the first diagram, where the constituents are completely segregated, the graph on the right shows the result of sampling and examination for the circle ingredient. If cumulative percentage of sample frequency is plotted against percentage of the circle ingredient a step-like graph will result as shown. Where a completely ordered arrangement exists, a horizontal line at 50% circle ingredient will occur, while the third diagram shows the results of perfect mixing. The $50 \pm s$, $50 \pm 2s$ and $50 \pm 3s$ points indicate the values of the percentiles when s is the standard deviation.

The statistical approach assumes that the process is 'fitted' by a binomial distribution,[10] in which case, if the fraction

$$\frac{g - p}{\sqrt{npg}}$$

is small (where $g = 1 - p$, n = number of particles and p = overall theoretical proportion of minor constituent, and the volume of each sample taken is the same), then the standard deviation is given by:[11]

$$S = \sqrt{\frac{\Sigma\left[\left(\frac{x}{n}\right) - \left(\frac{\bar{x}}{n}\right)\right]^2}{N - 1}}$$

where x = number of particles of minor ingredient in the sample, x/n = proportion of particles of minor ingredient in sample, $\bar{x}/n$ = mean proportion of particles of minor ingredient in the N samples, N = number of samples withdrawn from the mixture and s = standard deviation of composition.

$$S_r = \sqrt{\frac{p\ (1 - p)}{n}}$$

where S_r = theoretical standard deviation for a perfect mixture.

$$D_m = \frac{S_r}{S}$$

where D_m = degree of mixing.[2]

In the second or analytical theory developed by Coulson and Maitra[5, 6] the extent of mixing at any time after the start is proportional to the area of the surface between the ingredients. Thus

$$\frac{dA}{dt} = K(A_{\max} - A)$$

which on integration gives

$$A = A_{\max}\ (1 - e^{-Kt})$$

where $A_{\max}$ = maximum surface per

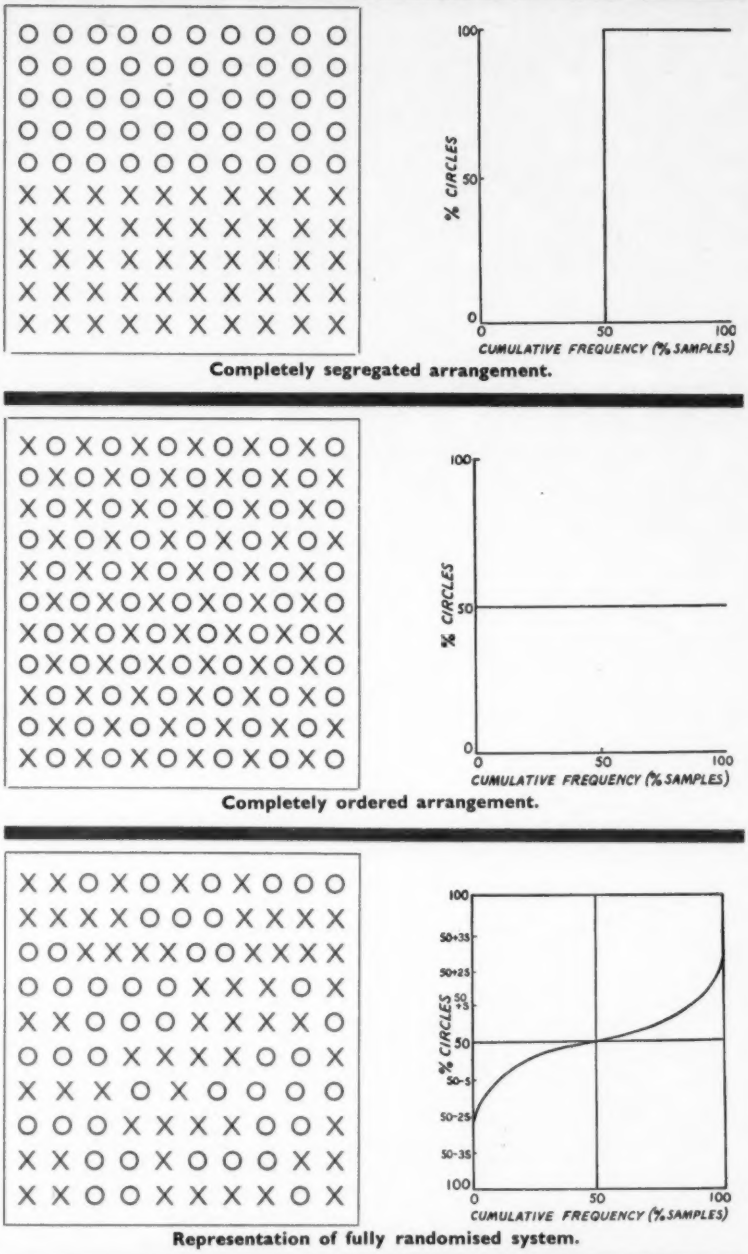

Fig. 4. Diagrams illustrating the statistical approach to mixing.

unit volume which can be attained in the system, A = total surface to volume ratio in time t and K = rate of mixing coefficient.

Scale of scrutiny

This parameter is important in mixing science and can be expressed alternatively as

$$\frac{\text{weight of sample}}{\text{weight of particle}} \text{ or } \frac{\text{volume of sample}}{\text{volume of particle}}$$

A ' fine-grained ' mixture is one with a large scale of scrutiny and *vice versa.*

Practical methods of determining mixing efficiency

None of the foregoing formulae can be applied without modification directly to mixing problems, but the principles have been used by several investigators.

For instance, Grey[1] used a photoelectric technique in which white and black powders were mixed in a machine. The reflectivity of the mixture was determined by a light and photocell, the photocurrent being measured. Grey then used the formula:

$$S = \sqrt{\frac{\Sigma(i - \bar{i})^2}{N - 1}}$$

where i = instantaneous photoelectric current (microamperes), $\bar{i}$ = average photoelectric current (microamperes), N = number of readings and S = standard deviation.

Michaels and Puzinauskas[7] withdrew equal volume samples from a mixture during processing at random points in the machine. The concentration of one of the ingredients was then estimated by chemical analysis. They then applied the formula

$$S = \sqrt{\frac{\Sigma(C_A - C_A{}^1)^2}{N - 1}}$$

where N = number of samples withdrawn, S = standard deviation, C_A = concentration of constituent A, and $C_A{}^1$ = mean concentration of constituent A.

They also defined a factor

$$\mathcal{J}_v = \frac{S}{S_o} = \frac{C_A - C_A{}^1}{C_A{}^1 (N - 1) (1 - C^1{}_A)}$$

where $\mathcal{J}_v$ = uniformity index and S_o = standard deviation for the initial state of the mix before treatment.

Adams and Baker[12] and Lacey[2] also used formulae based on the binomial distribution in their mixing work.

Coulson and Maitra[6] developed their theory to the point where practical application was possible and used it to study the performance of a small drum mixer. They determined the composition of samples by using a small hand lens on a small amount of material spread out very thinly. They applied the following expression to the results:

$$\log_{10} \frac{1}{1 - D_m} = Kt$$

$$D_m = \frac{N^1}{N}$$

where N^1 = number of samples which had approximately the theoretical composition, N = total number of samples, K = mixing coefficient, and t = time from the start of mixing. The samples were drawn at fixed intervals of time and the values of

$$\log_{10} \frac{1}{1 - D_m}$$

was plotted against time. The inclination of the resulting straight line gave the value of K.

It will be seen that the formulae enable criteria to be applied from which the effect of alterations in the mixing variables can be assessed. This is useful information, but it still leaves considerable scope for trial and error methods and these remain the basis for solving new problems in solids mixing.

Conclusions

In spite of considerable progress during the last 15 years in solids mixing techniques, much empericism remains. This is particularly evident in relation to new processes with unfamiliar ingredients.

The application of certain new theories enables mixing efficiency to be expressed in numerical terms, and these should be of great assistance in improving established mixing processes.

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Twenty-one years of sea-water magnesia

The attainment of a production rate of 150,000 tons p.a. marks a considerable achievement in the production of refractory magnesia by reacting burnt dolomite with treated sea-water at the Hartlepool, Co. Durham, works of the Steetley Co. Ltd. When this £5-million works was inaugurated 21 years ago with the installation of a pilot plant, a good deal of scepticism was encountered from those who considered that it was unnecessary to go to such lengths to obtain a material which could be won by simple mining operations in Austria. Britain has no indigenous deposits of magnesite, however, and the strategic importance of the plant was recognised as war became imminent. The economics of the process have proved to be such that the company is able to market magnesia at 70% of the import price. The bulk of production is supplied to the refractories industry, including Steetley's own brickmaking plants.

The plant takes dolime (magnesia lime) from its quarries at Thrislington and Coxhoe, where it is produced by burning graded dolomite in rotary kilns fired with pulverised coal. At the Hartlepool works, the dolime is slaked with fresh water to a fine powder in hydrator units, and made into a slurry which is classified to remove the impurities introduced from the fuel during calcination.

Sea-water is drawn by five centrifugal pumps through 950-ft.-long cast-iron pipes and stored in four tanks having a total capacity of 8 million gal. To remove calcium bicarbonate from the sea-water, the storage tanks feed into five pretreatment tanks where a small proportion of dolime is introduced. After treatment, the sea-water is pumped into reaction tanks and is mixed with the classified dolime slurry, and precipitation of magnesia takes place.

There are three reaction systems at the works, each consisting of two cylindrical reaction tanks fitted with agitators, and one settling tank equipped with continuously rotating thickener mechanism.

When the dilute suspension of magnesium hydroxide has settled, the sludge is transferred to washing tanks containing sea-water and then filtered on a battery of rotary vacuum disc filters. The filter cake, containing about 50% of solids, is calcinated in rotary kilns operating at a temperature of over 1,600°C. Finally the granules of *Britmag*—as the final product is called —are cooled and bagged.

A CPE Chemical Engineering Review

DRYING

By W. F. Calus, M.Sc.(Lwow), D.L.C.(Hons.), A.M.I.Chem.E.
(Department of Chemical Engineering, Loughborough College of Technology)

Fundamental studies; mass and heat transfer in drying; atomisation; effect of drying conditions on product quality; new types of drying equipment; etc.

THIS review covers the more important drying developments since approximately 1955. The specialised methods of drying such as freeze drying, infra-red drying and those techniques used for drying expensive materials are not treated.

The problem of drying is intimately connected with problems of heat transfer and mass transfer, and therefore it is necessary to make reference to these subjects. A relatively large proportion of the literature is devoted to spray drying and, in connection with this field, the design of the spray mechanism is of equal importance.

Operating data on full-scale drying equipment are rarely to be found in the technical literature, and yet such information is very necessary to make possible development of scale-up relationships.

Drying is still an art and much more fundamental work is needed to bring it to the level of development of the other unit operations.

General literature

The first volume of a work by Krischer and Kroell devoted entirely to drying technology was published in Germany.[6] It covers the fundamentals of fluid flow and heat transfer and application of these fundamentals to drying of a variety of materials.

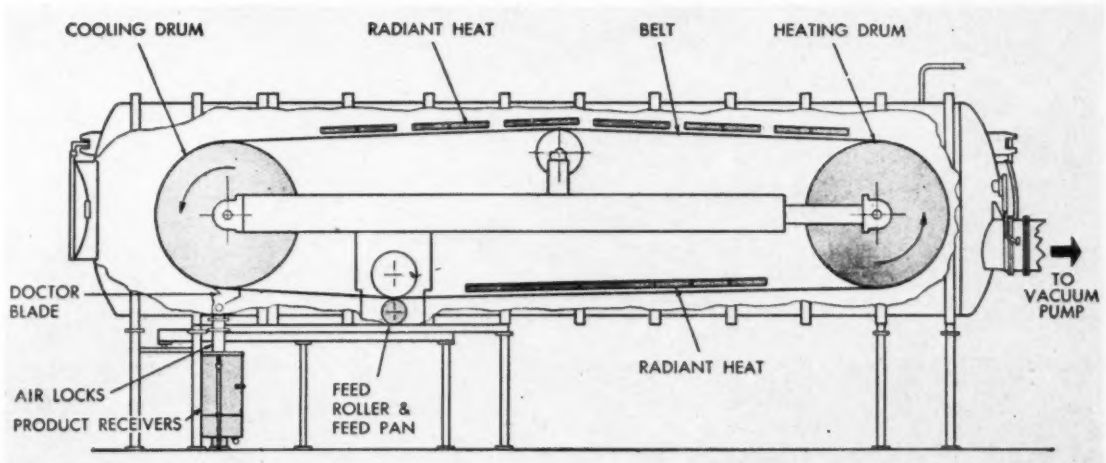
A good introduction to the unit operation of drying may be obtained from recently published books by Coulson and Richardson,[9] by Badger and Banchero,[10] by Molloy and others[12] and by McCabe and Smith.[15] Also a chapter on drying is included in the book on agricultural process engineering by Henderson and Perry.[11] Von Loesecke[13] gives description of numerous techniques and driers used in the food industry, and discusses the design of tunnel driers. A detailed survey of tunnel driers, underlining the theory of tunnel dehydration and of auxiliary equipment, is given by Kilpatrick, Lowe and Van Arsdel.[14]

A section on the combustion of liquid fuels in another book[36] is relevant to the operation of spray drying.

Mechanism of drying

Newitt *et al.*[5] have continued their investigations into the mechanism of the drying of solids. In previous papers[3,4] non-porous granular materials were covered. In the work of reference[5] mechanism of drying of porous granular material was investigated and compared with the drying mechanism of non-porous material under corresponding conditions. 'The form of the drying rate curves differs from those for corresponding beds of non-porous granular materials mainly through the capillary action of the internal pores of the granules in conveying water to the surface during the pendular state. Thus the rate of drying during the constant rate period is higher for porous than for non-porous material and, after the critical moisture content is reached, there follows an initial period having a very rapid reduction in drying rate and a prolonged second period in which the drying rate falls slowly.'

King and Newitt[16] experimented also on hot-plate drying of beds of non-porous granular solids which had one face exposed to a lateral current of air. The results emphasise the advantages of high air temperature and velocity and high surface temperature



[Courtesy: Chemical Engineering Progress

Schematic drawing of the Chain Belt Co. vacuum dehydrator.

for accelerating the rate in the early stages of drying. In connection with this work earlier papers by Newitt *et al.* may be consulted.[3, 4, 5, 47]

Gorling[21] summarises the existing results of the basic research on the mechanism of drying and makes an attempt to develop methods for predicting the most important characteristic points in the drying operation, from the knowledge of the special drying properties of the specific materials. This work alone gives 36 references to basic research papers.

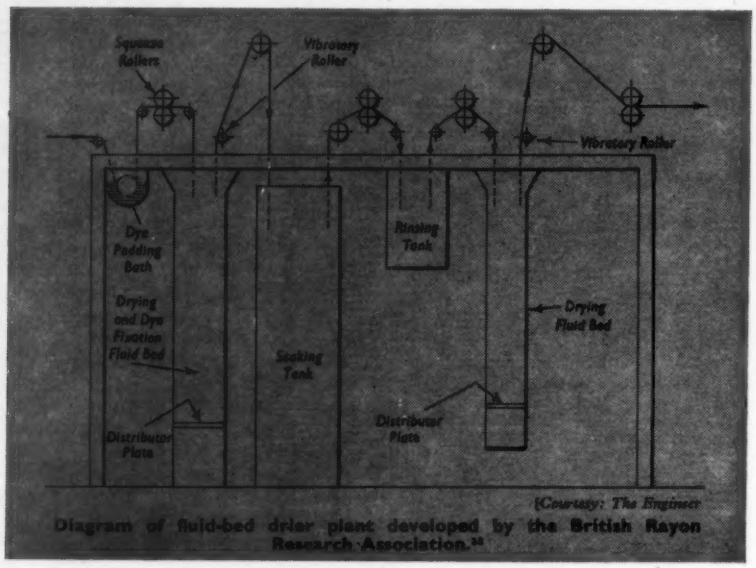
Ludt[28] investigated the mechanism of hot-surface drying of sand in still air. He found existence of a constant layer of moisture at the hot surface, which accounts not only for the constant rate period of drying but also largely for the length of the period. Equilibrium between the vapour rising through the bed and the water on the wet sand does not exist during periods of rapid vaporisation. Hot-surface drying of sand gives a drying rate curve of the same general form as that for air drying. This work gives 16 references to the appropriate literature.

Lebeis and Burtis[19] present results of an experimental study of the drying of spherical hydrogel catalyst particles in which they explored the effects of drying conditions on the drying rate and the physical properties of the catalyst. The authors state their final conclusions as follows:

(1) The drying rate of the hydrogel studied is proportional to the difference between air-dry and wet-bulb temperatures during the constant-rate period.

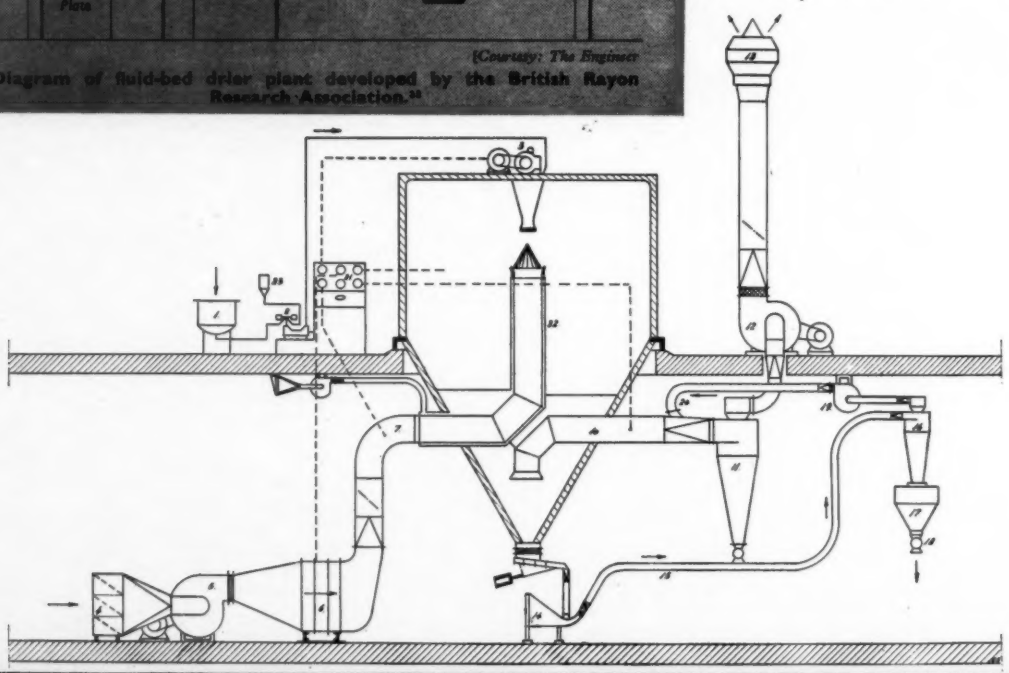
(2) During the falling-rate period the rate is proportional to the free-moisture content. The proportionality factor is a complicated and undetermined function of the difference between dry and wet-bulb temperatures.

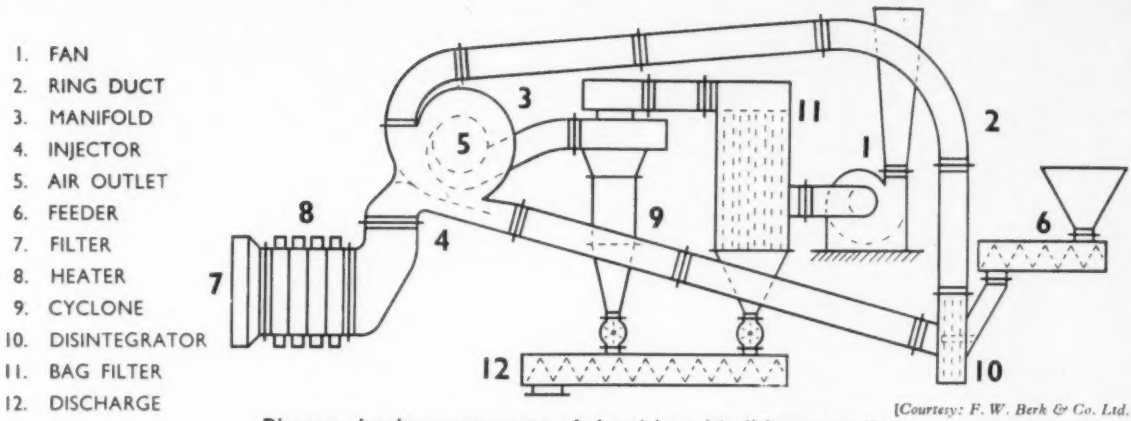
(3) Wet-bulb temperature level and drying rate during the falling-rate period are the major determinants of the density and large-pore volume of cracking catalysts prepared from this hydrogel. The higher the wet-bulb



(Courtesy: The Engineer

Diagram of fluid-bed drier plant developed by the British Rayon Research Association.[35]





[Courtesy: F. W. Berk & Co. Ltd.

Diagram showing arrangement of ring drier with disintegrator.[53]

temperature, the faster the catalyst may be dried to obtain the desired density.

(4) According to theoretical analysis, the important factors influencing uniformity of drying during the constant-rate period when deep layers are dried are bed depth, air velocity and particle size.

McEven and O'Callaghan[41] extended the previous work on through-flow drying of wheat grain with an investigation into the effect of varying air humidity. The results agree with those previously correlated on the assumption that diffusion is the mechanism of moisture movement. The previous works of McEven on drying of wheat grain were published.[42–46]

Mass and heat transfer

F. Call[18] gives a method of calculating unsteady-state diffusion coefficient in porous solids. The method requires experimental determination of the time at which the flux of material through the porous solid is a definite fraction, usually one half, of the steady-state flux.

A. C. Dreshfield[22] developed and employed a method for the measurement of the moisture content of fibrous sheets, such as paper or textile fabric, in hot surface drying by beta-ray transmission, and also of determining the migration of liquid within the sheet and location of zones of vaporisation by use of dyes. The method is applicable to other drying problems and offers a powerful tool for investigation of the mechanism of the simultaneous heat and mass transfer.

A work on the drying silica gel in a fluidised bed with the object of correlating heat-transfer coefficient based on particle area with Reynolds number is being carried out by Heertjes and McKibbins.[7, 8] Some of the results are published.[7]

Scale-up

Glover and Moss[2] developed a design method for full-scale driers based on simple laboratory experiment on the material to be dried. The experimental work was carried out on a laboratory through-circulation drier. The interpretation of the results led to the development of a design method for determining the area of a full-scale band through-circulation drier. The design calculation is illustrated by a worked example.

O'Callaghan[30] showed that the performance of a countercurrent flow wheat drier may be predicted from experimentally determined data in drying a single layer of wheat grains.

Sprays and droplets

Fraser and Eisenklam[17] provide a survey of the atomisation techniques and the major spraying applications of interest to the chemical engineer. The paper includes 30 references.

Ranz and Hofelt[31] propose a standard test method for determining the drop size distribution of a nozzle spray, using the principle of inertial impaction in a special flow system. The authors describe the equipment used and the experimental procedure.

Magarvey and Taylor[35] noted that large drops, of the order of 12 mm. in diameter, in free fall are deformed to such a degree, before terminal velocity is reached, that the centre of the flattened drop bulges upward and the drop opens like a parachute. Smaller drops assume a reasonably regular shape at the terminal velocity.

Herring and Marshall[49] investigated the performance characteristics of disc atomisers of the straight, radial-vaned type and determined how the weight and drop-size distribution of water sprays were influenced by the diameter, speed, vane dimensions and by the feed rate. The paper includes 19 references, some of them covering the field of pressure nozzles.

The effects of the physical properties and volume flow rate of liquids on the surface area of sprays produced by a pressure type of atomising nozzle were determined empirically by Consiglio and Sliepcevich.[51] They correlated the specific area of the sprays by an equation of two dimensionless groups in terms of the variables: surface tension to the –1.0 power, kinematic viscosity to the –0.4 power, and volume flow rate to the 2.4 power. The volume flow rate is correlated by an equation of two dimensionless groups with the variables: viscosity to the 0.17 power, density to the –0.58 power and spray pressure to the 0.42 power.

Drying conditions and the product quality

Jopling[34] investigated the influence of drying conditions on gelatin and found that the minimum swelling occurs when the temperature of the layer during drying is about 35°C. When dried at a higher temperature, the layer is 'sol-like' and bonding does not occur until the layer is swollen or conditioned at high relative humidity.

Coulter[37] considers the factors involved in the production of spray-dried milk. The influence of the spray-drying conditions on the quality of wheat gluten are described by McConnell.[38]

Buckham and Moulton[52] experimented on a vertical cylindrical co-current-flow spray drier with the object of studying two distinct phases of spray drying: the recirculation of gas within the drying chamber and the relationship between final particle diameter and original spray-droplet diameter. Gas recirculation in the

drying chamber occurred to the extent of about three-fourths of complete mixing as indicated by vertical drying-zone temperature and humidity distributions. The principal product property determined was the ratio of the final to the original particle diameter and this was found to increase with both feed concentration and original particle diameter. This paper includes 17 references.

Drying methods

Hauschild[32] reviewed the application of spray driers to drying of synthetic detergents. Particular attention was devoted to the drying plant design, choice of the plant, and the effect of the operating conditions on the final product.

L. Walter[39] discusses the factors to be considered in the selection of a drier for a given duty and reviews a number of types of driers from the point of view of their applications and economics. The article is illustrated with a table for drier classification based on methods of heat transfer in evaporation of moisture. However, the author is of the opinion that the best classification of driers would be one based rather on material characteristics than on drier design groups or methods of moisture evaporation.

Lane and Stern[20] present a brief account of drying with superheated vapour and stress the economic advantages of this operation over that of drying with hot air. They also point out that the oxygen-sensitive materials can be dried in this way without oxidation hazards.

Chain Belt Co.[23] developed a continuous vacuum drier for drying chiefly pharmaceutical and food products sensitive to temperature and oxygen. In this drier the heat is supplied by a radiant-heating section, a steam-heated drum, and then a second radiant-heating section. The product is then cooled by passage over a cooling drum also within the vacuum vessel. The feed is applied, and the dry, cold product removed under vacuum. The other advantages of this drier are short drying time and lower cost than in batch drying.

Another publication[24] gives a description of a spray drier developed by Niro Atomiser A.S., Copenhagen. The cylindrical portion is 30 ft. in diameter by 10 ft. high and on this is added the conical section with 60° included angle. The drier removes 6 tons of water from 15 tons of a concentrated kaolin slurry per hour. A thermal efficiency of 80% is claimed for this unit.

The *Manufacturing Chemist*[25] gives a detailed description of a great variety of drying equipment developed in the last few years. The manufacturers of the equipment are named. The driers described include: tray driers, cross-flow ovens, vacuum driers, conveyor-type driers, pan driers, spray and pneumatic driers, jet spray driers, rotary driers and infra-red driers.

Comings and Coldren[26] developed a jet spray drier of unusual design and explained the details of its operation. McLain, Comings and Myers[27] introduced a number of alterations to that design and experimented on the modified jet spray drier with sodium sulphate solution. The effectiveness of the equipment is attributed to the fine spray produced by the gas-liquid atomiser and intimate mixing of the hot gases with the spray. Owing to the high velocities employed the size of the plant is very small and, the time of contact of the gas and liquid being very short, use of drying gas at high temperature is permissible, even with heat-sensitive materials. Wall deposition of the product can be eliminated under the proper operating conditions. The authors admit that heat and power requirements are higher than those of the conventional spray driers. The two papers include a number of useful references, the first 33 and the second 37.

A fluid-bed pilot plant for drying textile materials has been described,[33] the plant being developed by the British Rayon Research Association. The material in sheet form is dried by passing it through a fluid bed of glass beads which are up to 1 mm. in diameter. The temperature of the fluidising medium is chosen appropriately. The drying rates are said to be three times those of conventional driers used in the textile industry. Uniform heat distribution in the fluid bed is especially advantageous for the drying of textiles. Capital costs and operating costs with fluid-bed driers are expected to be much lower as compared with the conventional driers.

The Brookhaven National Laboratory[40] developed a combination of ball mill and rotary kiln. The amount of grinding done by the balls is negligible, but they serve to keep the solids from agglomerating and to improve the heat-transfer rate. The product produced is roughly spherical, free flowing and fairly uniform in size.

Miskell and Marshall[50] studied, on a pilot-plant-scale rotary drier, the effects of drier loading on the degree to which solid particles become dispersed. They found that on their drier the deviation from the average retention time was a minimum at a drier holdup of 7.5 to 8% and that above or below this holdup the deviation increased. Radioactive tracer technique of analysis was used.

F. W. Berk Co. Ltd.[53] recommend their pneumatic ring drier for drying powdered, granular and flaky materials, filter cakes and some pasty substances. Owing to the high velocity of the air or other conveying and drying medium, the plant has relatively small dimensions. The solids off-take is so arranged, by the application of the principle of centrifugal force, that only dry material is removed from the system and the still-wet material continues circulation. Also, control of particle size of the material treated is possible if a disintegrator is incorporated in the ring duct.

Miscellaneous

Nissan, Kaye and Pilling[1] applied an electronic digital computer to calculations in a problem of drying of sheet material on steam-heated cylinders.

The Quaker Oats Co.[48] has on the market a continuous moisture content analyser. The instrument is capable of analysing, recording, and controlling the moisture content. The accuracy of the instrument increases as the range of the particle sizes narrows. The principle of the instrument is measurement of the dielectric effect by capacitive reactance, when a stream of solids is forced between the electrode plates. The instrument is located in such a way that a small portion of the moving solids is diverted and forced through it, to join the main stream on leaving the instrument.

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(*Concluded on page* 395)

Chemical Engineering for a Pressurised-water Nuclear Reactor

By F. R. Paulsen, B.Sc., Ph.D., F.R.I.C., F.C.S.

The Shippingport, Pennsylvania, atomic power plant (described in CHEMICAL & PROCESS ENGINEERING *in August* 1956) *has received wide publicity as America's first large-scale producer of civilian nuclear power, but not so much has been heard of the painstaking chemical engineering and chemical investigations which helped to make it possible. This article describes how the problems of corrosion, radioactivity, fuel element failure, explosion hazards and waste disposal were tackled.*

THE Shippingport reactor came into operation on December 18, 1957, and achieved its design power of 60Mw. five days later. Thus, slightly more than three years after the formal ground-breaking ceremony, one of the major phases of America's nuclear power development programme came to realisation. The commencement of operations at the Shippingport plant represents the fruition of a dream, in which architects, physicists, and engineers got together to plan what was to be one of the most advanced concepts of modern reactor technology—the large-scale pressurised-water reactor system. In the project, the part played by the chemists and chemical engineers is all too easily overlooked, but without them, the whole planning and concept could have broken down.

The chemistry of the pressurised-water reactor, in general, incorporates the accrued work of some years of intensive research. Problems of corrosion, radiolytic dissociation of water, fouling of heat-transfer surfaces, and system activation by impurities settling out of the coolant, had all to be taken into account.

Corrosion problems

When ordinary water was selected as the heat-transfer medium in both cooling systems, the problems of corrosion and radioactivation reared their heads. The heat from the core, amounting to 790 million B.Th.U./hr., has to be removed by ordinary water circulating in four loops. In each loop the rate of water circulation was to be 7.59 million lb./hr. at a speed of 34.8 ft./sec. in the main piping, and at an average temperature of 523°F. and pressure of 2,000 p.s.i.a. Such conditions, as might be expected, could give rise to grave corrosion problems, unless great care was paid to the choice of constructional materials. In general, stainless steel No. 304 was selected, though the metal separating the fuel elements from the coolant, where the temperature gradient was more severe, was zirconium alloy. Bronze could be used in the cooler parts. Corrosion of the stainless steel is inhibited by raising the *p*H of the coolant to the range 9.5 to 10.5, by additions of lithium hydroxide before start-up. During actual operations this *p*H was maintained by the automatic addition of lithium hydroxide ion exchanger in a by-pass purification system. The high alkalinity not only reduces corrosion, but keeps more of the corrosion products in solution, thus reducing the fouling of the core, and limiting the activation of the system by corrosion products.

Corrosion products may become highly radioactive under the action of neutrons from the core, and give rise to radiation hazards. Danger from this source is minimised not only by choice of stainless steel, but also by restricting the coolant water to a closed primary circuit. Heat from this pressurised system is then passed on to the secondary water circuit by heat exchangers, and no activity can find its way to the turbine.

Corrosion 'crud' can also lead to damage by upsetting the very delicate thermal balance in the core. The latter is a complex arrangement based on the seed-and-blanket concept. In the seed is enriched uranium, in which fission occurs, spare neutrons being emitted. Some of these are reflected back into the seed by the blanket, and maintain the chain reaction. Others are absorbed by the blanket, which is of natural uranium. Here there is fission, giving heat and neutrons, and also some conversion of uranium into plutonium. The picture is even more complicated by the fact that as uranium is used up in the seed, heat production gradually falls off, while it increases in the blanket, due to growth of plutonium. There is obviously need for a very carefully planned distribution of the coolant water in the core, and anything likely to upset this must be avoided.

Fuel elements

Modern practice requires that power plants should be used to the maximum extent, be operated continuously over long periods, and be readily accessible for maintenance. Thus, fuel element failures must be very rare, and have little impact on the operation. Radiation damage and corrosion of fuels with high uranium metal content lead to intense development programmes on uranium dioxide, the most promising alternative material.

There were many questions to be answered here, and tests had to be done before the uranium dioxide could be assured as safe to use. One of the problems concerned the extremes of temperature and other environmental conditions which the uranium oxide elements might withstand without damage or melting. Again, information was required on the possible extent to which an element could fail, and whether such failure could progress to other elements in the fuel assembly. Such questions could be answered only by tests under rigorously simulated operating conditions.

For this purpose several irradiation test facilities or in-pile test loops capable of operation at high temperatures and under intense radiation were designed and constructed. Uranium dioxide fuel elements containing deliberate defects in the cladding were irradiated at various levels in high-temperature water and with various geometries of tubes and pellets. Unexpected limitations on maximum power without the melting of the

oxide were found, but fortunately these were in excess of the P.W.R. design values. Tests also demonstrated that, in the absence of oxygen, the uranium dioxide was chemically stable in neutral and alkaline water.

To determine whether failure progresses from one element to another, a bundle of the pressurised-water reactor fuel rods was irradiated, with one rod bent so that it touched a neighbour. To make the test more exacting, the cladding on the bent rod was weakened at the point of contact, and the rod was filled with water, to produce sufficient steam to cause rupture. Even under these conditions there was no evidence of progressive failure.

Guarding against fuel element failure

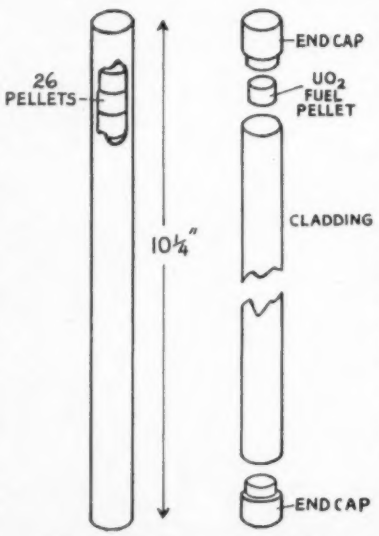
It appeared obvious, then, that uranium dioxide fuel would be stable even if exposed to coolant water through defects in the cladding, and that only individual fuel elements would fail. The consequences of operation with faulty fuel elements still remained to be studied. For this purpose the release of fission products to the water was measured, and a final corrosion test of one defective element was made over a period of rather more than one year. The released fission products consisted largely of halogens (bromine and iodine), noble gases (krypton and xenon), and alkali metals (rubidium and caesium), together with small amounts of alkaline earths (barium and strontium), and minute traces of the rare earths (the lanthanide elements). The data obtained in this way proved useful in evaluating the whole fission product problem for the P.W.R. The nature and quantities of fission products released by a faulty element would allow operation of the reactor even in the event of the failure of a large number of elements; far larger, in fact, than is considered likely during the design lifetime of the core. It was also found that the plant could be made accessible for maintenance by the use of a continuous ion-exchange purification process, and that wastes could be adequately disposed of by the combined use of ion-exchange, storage and decay. The systems of waste-disposal were designed conservatively on the basis of the data provided by the test programme on failed fuel elements.

Means for locating leaking fuel elements were developed and incorporated in the plant design. The method uses the emission of delayed neutrons from certain short-lived fission products. Based on detailed observations obtained in irradiation tests, a successful detection and location system was devised. Coolant water was sampled from pairs of fuel elements in the core, and passed to the neutron monitors. The sampling is done cyclically, so that each element is tested once in each cycle. If the delayed neutrons indicate a defective element a warning is given in the control room. Previous optimism concerning the sensitivity of this system proved unfounded, and only one major or several minor perforations in a single channel will be detectable. This is considered adequate, however, for ordinary purposes. Should it subsequently prove possible to reduce the trace impurity uranium in the zirconium, the sensitivity might be appreciably improved.

A method was also evolved for the decontamination of systems rendered inaccessible as a result of radioactivity. Arising from failed uranium oxide fuel elements, this activity has proved amenable to treatment. An irradiation loop has been successfully decontaminated and restored to use, after a uranium oxide fuel element had failed in it.

Explosion hazards of coolant liquids

Radiolytic decomposition of coolant liquids is an important feature which must be borne in mind in reactor design. In reactors employing heavy water as coolant and moderator, the conversion of the liquid, under the action of radiations, into a gaseous mixture of deuterium and oxygen not only leads to explosion hazards, but also to possible heavy financial losses, unless some recombination unit can be included in the design. While the financial question does not arise in the case of ordinary water, the explosion hazard does arise. Automatic instruments were developed for determining the hydrogen and oxygen levels in the coolant liquid, and these were incorporated in an analytical and sampling unit for the reactor system. To suppress the formation of oxygen from the dissociation of water, extra hydrogen to the extent of 25 c.c. per kg. is maintained in the coolant. This has also an anti-corrosion effect.



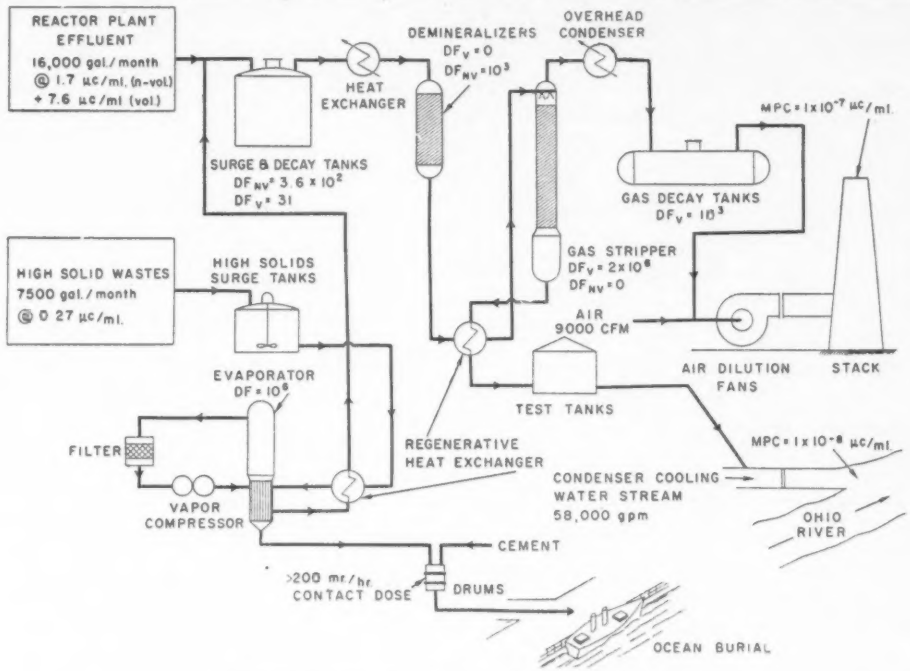
P.W.R. uranium dioxide fuel rod.

Another problem for the chemical engineers was the investigation of the possible reactions between zirconium and water. Assuming a rupture of more than 6-in. diameter in the reactor coolant system pressure boundary below core level, with the minimum expected flow of 1,500 gal./min. from the safety injection system, a maximum of 20% of the blanket region of the core could melt. During such an accident, 4.5% (at most) of the 9.38 tons of zirconium associated with the heat transfer areas in the core would react with water or steam. The reaction would not start for some minutes after the rupture and would be in the nature of a self-propagating fire. Heat from the exothermic zirconium-water reaction, and from the combustion of the hydrogen formed in this reaction, could only slightly increase the pressure in the plant container, and the total pressure would still be well below that for which the container was designed. If the hydrogen gas does not burn as it is evolved, but mixes with air and steam in the plant container, the hydrogen concentration will be well below the inflammable limit, and neither detonation nor fire could result.

Radioactive waste disposal

Chemical engineers have been intimately concerned with the design and development of systems for the disposal of radioactive wastes from the P.W.R. plant. Liquid waste will be pumped to underground tanks for monitoring, and it will either then be allowed to decay before being dumped at sea, or processed by demineralising resins and a gas stripper.

Mixed-bed demineralising resins remove solid radioactive materials as well as particulate matter, and the processed liquid, after monitoring, will be mixed with condensate and discharged into the Ohio River. Dissolved fission gases will be removed by



Effluent treatment and disposal at Shippingport.

a gas stripper under slight vacuum, and stored in steel tanks until decayed enough to allow discharge to atmosphere. Highly concentrated liquid effluents will be processed through a vapour compression evaporator. The distillate from this will be sent to the liquid surge tanks, and the concentrate mixed with cement, drummed, and dumped at sea. Spent resins are diluted with water, and passed to underground storage tanks. Here the solids are allowed to settle, for decay, while the liquid is decanted and sent to liquid decay tanks for further processing.

This very limited selection of subjects will indicate clearly the very close association of chemical engineers with the Shippingport project, and their responsibilities in solving the thorny problems which preceded the successful operation of the nuclear power plant.

Drying

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THE CHANGING PATTERN OF GAS MANUFACTURE

Part 2—The New Techniques

By A. R. Myhill, F.R.I.C., M.Inst.Gas E., M.Inst.F.

In Part 1 of this article, published in our September issue, reference was made to the development of completely new methods of making gas from coal without the co-production of coke. The principles upon which these methods are based are discussed in this concluding part of the article.

BEARING in mind the desirability of devising methods of gas production which can deal with coals of any type, it has been realised that the older methods of total coal gasification are unsuited to the production of base-load gas, largely by reason of the low calorific value of the product.

In contrast, the new methods present means by which the calorific value and combustion characteristics of the gas can be controlled over a wide range, without the necessity of oil enrichment. The principles involved include pressure-gasification, hydrogenation of solid carbonaceous materials, and catalytic synthesis of methane from carbon monoxide and hydrogen. The reactions of both hydrogenation and methane synthesis are exothermic, and are represented by the following equations:—

Hydrogenation:

$$\underbrace{C+2H_2}_{2.46\ \text{therms}} \rightarrow \underbrace{CH_4}_{3.83\ \text{therms}} + 0.35\ \text{therm}$$

Catalytic synthesis:

$$\underbrace{CO+3H_2}_{4.91\ \text{therms}} \rightarrow \underbrace{CH_4}_{3.83\ \text{therms}} + H_2O + 1.08\ \text{therms}$$

Since hydrogenation is a means of gasifying carbon, the reaction is accompanied by an increase in potential heat as gas. On the other hand, methane synthesis results in a decrease in liberated potential heat in gas. Because the quantity of heat evolved in hydrogenation is less than that evolved in methane synthesis, it follows that the former process operates at a higher thermal efficiency than the latter. Although this is an advantage, the synthesis of methane must not be overlooked as a possible useful source of enrichment, since it could be used in conjunction with the gasification of certain materials (*e.g.* coke and breeze) which cannot be hydrogenated. Moreover, it is not limited to pressure operation, as is hydrogenation, and is closely related to the synthesis of liquid hydrocarbons, a subject likely to assume considerable importance as a process allied to gas production in the future.

Lurgi process

The Lurgi process has been operating successfully in Germany for a number of years, but conditions have, until recently, been very different from those obtaining in Britain in that it was originally designed to gasify brown coals and lignites. The high reactivity and freedom from caking possessed by these fuels make them particularly suitable for the process, which, in its original form, is not capable of dealing satisfactorily with the usual carbonisation coals. The Gas Council has included in its research programme large-scale tests on modifications of the Lurgi system, with particular reference to making it applicable to weakly-caking bituminous coals.[11, 12]

In principle, the process consists of the high-pressure gasification of coal (5 to 30 atm.) in the presence of oxygen and steam. In addition to straight carbonisation the following basic reactions occur:

(*a*) Combustion of carbon to CO_2 to provide heat for subsequent reactions (water-gas production, etc.)

(*b*) The water-gas reaction:
$$C+H_2O = CO+H_2$$

(*c*) The water-gas shift reaction:
$$CO+H_2O = CO_2+H_2$$

(*d*) Hydrogenation (methane production) by combination of carbon of the coal with nascent hydrogen from carbonisation.

The necessary use of high pressure has led logically to the adaptation of its advantages in directions other than simple gasification, as, for example, in purification, distribution and storage. Since so large a power consumption is necessary, the aim should be to apply it in such a way that benefit can be obtained throughout the whole system. In particular, the amount of power involved in gas compression for the removal of carbon dioxide is almost sufficient for the separation of the air needed to supply the oxygen. Thus, by separating the air, rejecting the nitrogen, and adding the oxygen to the steam, the whole process, including a steady supply of steam from the boiler-cooler, can be made continuous.[11]

Fig. 4 shows the conventional Lurgi layout from generator to purified-gas outlet. The vessels are considerably smaller than those used in conventional practice, and comprise a cooler for condensing undecomposed steam and tar, followed by an oil scrubber for removing benzole and light oils. The gas at this stage contains up to 30% of CO_2 which is reduced to about 5% by simple water-washing under pressure. The treatment also removes most of the sulphur compounds, including 99% of the hydrogen sulphide, the residue being absorbed in an iron-oxide purifier.

A notable example of a Lurgi plant working on these lines for the production of town gas is the 30 million cu. ft./day installation at Morwell, Australia, which uses brown coal in briquette form. Plans are in hand to increase the output to 60 million cu. ft./day. The plant incorporates a Linde-Fränkl air-liquefaction unit for oxygen production.[13]

Tests made by the Gas Council on the practicability of using British carbonisation coals in a Lurgi generator have given encouraging results. Certain modifications are necessary in the plant and process. These in-

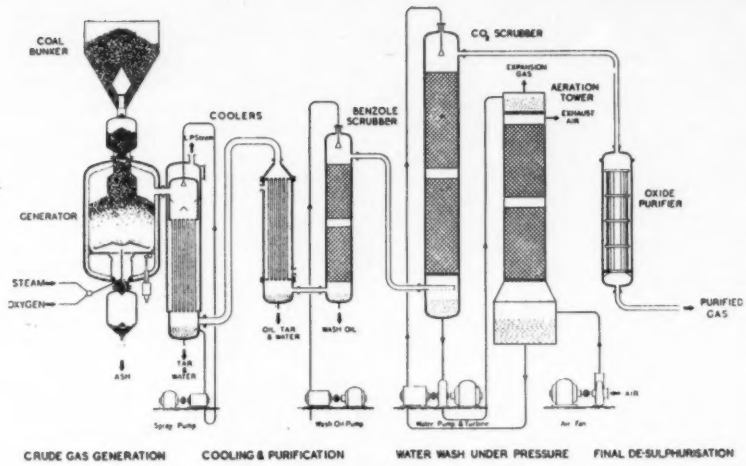

Fig. 4. Layout of Lurgi process.

clude methods of overcoming agglomeration of the fuel by incipient caking. By fitting the coal feeder with knives or ploughs which rotate in the upper layers of the fuel bed, no difficulty was experienced, even with a highly fusible coal (type 702).

The question of increasing the calorific value of Lurgi gas is an important consideration. Using the conventional type of plant, calorific values rarely exceed 400 to 450 B.Th.U./cu. ft., the value depending on the type of coal used. Methods used, or proposed, include enrichment with petroleum gases, natural gas or methane from a catalytic synthesis plant, although the last may add considerably to the cost of gas production. Measures for promoting increased methane formation within the Lurgi generator itself are now being investigated.

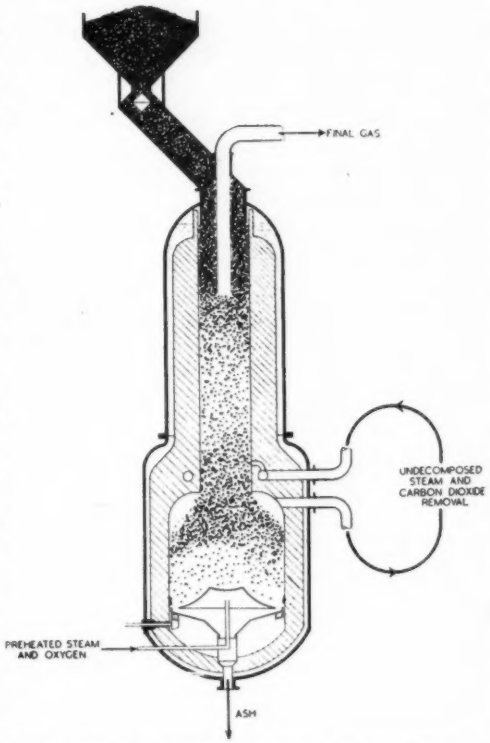

Fig. 5. Modified Lurgi generator with upper hydrogenation chamber.

In the upper part of the fuel bed, where most of the methane formation takes place, the presence of hydrogen tends to suppress the evolution of further hydrogen from the coal in the free state, and to favour the combination of hydrogen and carbon. This reaction is limited by the concentrations of carbon dioxide and undecomposed steam. Investigations are in progress on the construction and operation of a modified design of generator having two zones, representing the locations of the predominating reactions. The upper zone is the distillation and hydrogenation section. Gas arising from the lower section could be taken from the top of the lower zone through a special offtake, and the CO_2 and excess water vapour removed, afterwards re-introducing it into the upper zone in a preheated state. The partial pressure of hydrogen in this section would thereby be increased, and the formation of methane augmented. This arrangement is shown in Fig. 5.

Steam-cracking efficiences in the Lurgi plant are very low on account of the necessity for using a great excess over and above that necessary for gasification, in order to control the temperature of the fuel bed, and to avoid clinker troubles. This seriously lowers the general thermal efficiency of the system. Tests are being made by the Gas Council on the use of a Lurgi generator working as a slagging producer, in which fuel-bed temperatures are sufficiently high to maintain the ash in the molten state, in which form it can be periodically tapped off.

An important result of the investigations on bituminous coal is that the output of a Lurgi generator can be at least doubled if fines below $\frac{1}{4}$ in. are excluded.

A further improvement which might have considerable potential value where town-gas manufacture is carried out in alliance with chemical manufacture is the *Rectisol* process, in which a wash with an organic solvent such as methanol at –50° C. replaces the conventional washes with oil and water and the final purification from H_2S with iron oxide. The solvent removes CO_2, H_2S, organic sulphur compounds, light spirit, and gum-forming constituents. Since the removal of sulphur is virtually complete, the gas is sufficiently pure to be passed directly to a catalytic synthesis plant if this is desired. The absorbed H_2S and CO_2 are liberated from the solvent by releasing the pressure, and sulphur recovered from the H_2S by combustion in a Claus kiln.

Faith in the efficacy of the Lurgi process as a means of providing base-load gas in Britain is evident by the decision of the Scottish Gas Board to install a large plant at Westfield, Fife. Preliminary calculations lead to the expectation that the plant will make gas more cheaply than any other method in commercial use in Great Britain, using low-grade, open-cast coal. This will enable substantial savings to be made in high-grade coal, and will produce valuable by-products. The project, including its associated distribution extensions, will cost £6½ million and will take five years to complete. The generators will eventually produce about 22 million cu. ft./day at a calorific value of 400 B.Th.U./cu. ft.

Enrichment will be by means of oil hydrogenation (Dr. F. J. Dent's process), bringing the total volume to 30 million cu. ft. (During the interim

stages enrichment will be by butane obtained from petroleum refineries.) The plant lay-out is somewhat different from that previously adopted. Gas from the generator, after cooling, deposits tar and ammoniacal liquor, and then passes to a light-oil and benzole-recovery plant. Following this, it enters a catalytic-conversion plant for increasing the concentration of hydrogen by the interaction of steam and carbon monoxide, and the CO_2 is afterwards removed by high-pressure washing with a solution of potassium carbonate. Enrichment by light-oil hydrogenation follows, raising the calorific value of the gas to about 700 B.Th.U./cu. ft., after which it is treated in another benzole-recovery plant operating to make high-purity benzole, and reducing the calorific value to normal town gas standard.

The final stage is the removal of H_2S in pressure oxide purifiers. Gas leaves the plant at a pressure of 250 p.s.i., enabling distribution to be carried out over long distances without additional boosting. The Scottish Gas Board proposes to operate its own oxygen plant. Present-day costs of tonnage oxygen when making 200 to 250 tons/day are of the order of £3/ton, but it is anticipated that integration with steam and power production will reduce this to about £2.

Processes using powdered coal[11]

Although powdered-coal techniques for producing town gas have not yet been adopted on the commercial scale, acceptable processes are already envisaged, but considerably more investigation is needed before their economics are proved.

A consideration which might show advantages of powder gasification over fixed-bed processes using oxygen and steam is that, although the use of oxygen constitutes a convenient method for obtaining a high pressure, its only real function is to provide a continuous supply of heat for steam decomposition. The pressure used is that of the steam, and, if more economical methods of liberating heat under pressure are developed, the use of oxygen may be discounted.

Dent[11] has pointed out that, in the case of fixed-bed gasification, 'the several stages involved in the conversion of coal into gas require different temperature levels; and heat-exchange, methane formation, CO conversion, gasification in steam, and combustion with oxygen occur progressively at the increasing temperatures prevailing, as the fuel descends against the gases. It is more than can be expected for conditions to be the optimum for each stage. Powder techniques should facilitate the separation and individual control of the stages.'

Powder techniques suggested for gasification processes include fluidisation, fully suspended gasification, and a combination of the two. A suggested scheme of powder gasification[11] with individual control of the stages is illustrated in Fig. 6. This scheme, allowing for the pressure energy of the gas produced, gives an overall thermal efficiency of 80%, including oxygen production, and allows of the controlled production of town gas of any normally desired characteristics.

Which way are we going?

The gas industry is affected by so many external and unpredictable factors that it would be foolish to attempt to make an even approximate prophesy concerning its future plans.

As the writer sees it, the industry will be faced with increasing demands for its products (in any case until we know how far the implementation of nuclear power is likely to change the picture). For many years to come, it will have to continue to balance its aims between supplying gas alone or gas plus solid fuel, although present trends appear to be in the direction of making town gas by means which must reduce the quantity of coke available for sale.

It seems likely that base-load gas will be made by a combination of carbonising plant and total gasification of non-caking coal, in plants based on the principles of the Lurgi process, in controlled stages. The high capital costs of both the above systems make it imperative to employ them for all-the-year-round working, if the cost of gas is to be kept within economic limits. Gas-making from oil requires less capital expenditure per unit of gas produced, although the higher costs of materials might more than nullify any gains on this head. Such plant can, for intermittent working, be started up, shut down, or varied in respect of output made far more readily and economically than carbonising plant, and it is best employed for implementing base-load gas at peak hours or to meet part of the extra winter load.

While the use of foreign oil or imported natural gas will undoubtedly play a very important part in the near future, there will always be a certain measure of uneasiness regarding reliance on sources which are not indigenous, and it would therefore appear highly desirable to develop as fully as possible those processes, such as hydrogenation and methane synthesis, which will give all the control needed to maintain the required quantity and quality of gas from coal alone. Since such processes can be conducted in internally heated systems requiring no large reservoir of sensible heat such as has to be provided in the

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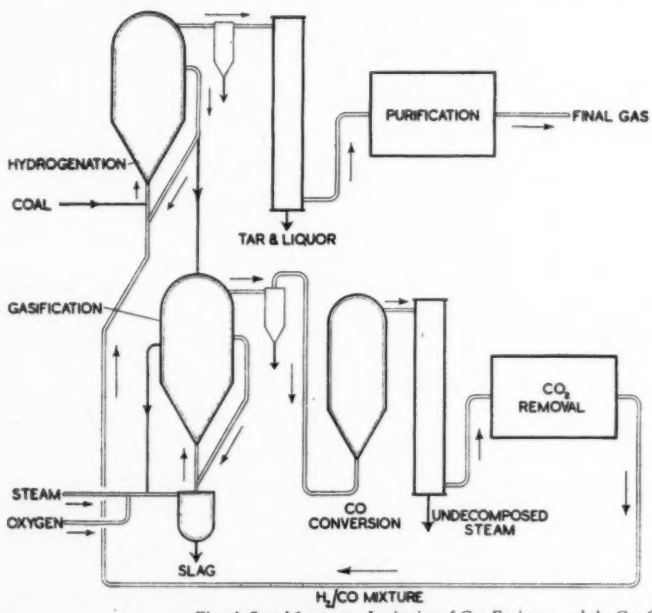
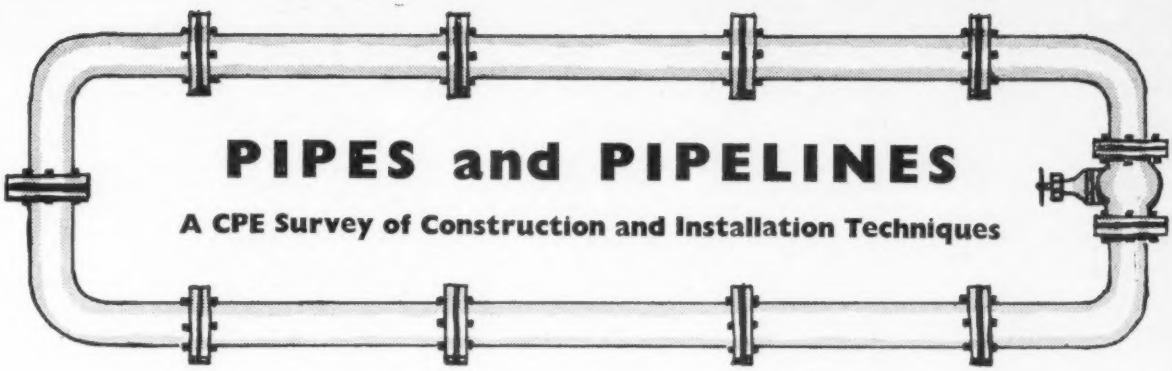


Figs. 4, 5 and 6 courtesy Institution of Gas Engineers and the Gas Council

Fig. 6. Flow sheet, pressure gasification for powdered fuel.



FACTORS IN THE DESIGN OF PIPELINE SYSTEMS

By A. E. Crisp, M.A.(Eng.), M.I.C.E., A.M.I.Mech.E., M.I.W.E., **and P. W. Heselgrave,** B.Sc., D.I.C.
(Pencol Pipeline and Engineering Consultants)

The aim of this article is to treat in a general way some of the principal aspects of the design of pipeline systems for the transport of fluids in the chemical, petrochemical and petroleum industries, and also for the transport of coal and natural gas, industrial gases, coal, cement, sand and a variety of other materials.

THE main considerations affecting the design of a pipeline system are:

(i) The characteristics of the fluid to be conveyed.

(ii) The quantity of fluid to be transferred and whether this quantity of fluid will flow through a line of practicable diameter under the available gravity head or whether such a head must be created by pumping.

(iii) The overall scheme of which the pipeline is a part, *i.e.* the lengths of the pipe runs required; whether the temperature of the fluids needs to be maintained and whether the pipeline must be taken underground to preserve surface facilities, etc.

These principal factors are discussed as follows.

(i) Characteristics of the fluid

The characteristics of the fluid can be usefully divided into two classes: (*a*) the physical properties which determine its pumping characteristics, *i.e.* its density, viscosity and the variation of both these with temperature and pressure, and the homogeneity of the fluid (whether it comprises one or two phases, *e.g.* an emulsion slurry, etc.) and (*b*) chemical properties which determine its behaviour when in contact with possible materials of construction: its inflammability, toxicity, etc.

(**a**) **Physical properties.** Clean fluids are generally characterised by a viscosity which is constant and independent of rate of shear. For heterogeneous fluids the resistance to shear is a function of the rate of shear. The two types of fluid require different methods of calculation.

(1) *Clean liquids.* A considerable amount of theoretical and investigational work has been carried out on the flow of fluids in horizontal pipes and the formulae and curves available for the calculation of pressure drop along the pipe for given rates of flow of the fluid and for different diameters of pipeline are sufficiently accurate for all practical purposes. The curves and formulae are not reproduced here since they can be obtained from the literature.[1, 2, 3, 4] The analysis assumes that the viscosity of the liquid is a constant; this is not always so even in the case of clean liquids. When the temperature of the fluid being pumped changes markedly it is necessary for the purposes of calculation to divide the pipelines into sections, compute the mean temperature of the fluid over the section, and use the viscosity at this temperature to compute the pressure drop over the section. Such calculations cannot be made with great accuracy because of the uncertainty of the heat-transfer coefficients.

(2) *Heterogeneous fluids.* A considerable amount of work has been carried out on the flow of heterogeneous fluids along pipelines, but in view of the very wide range of conditions which can be met, reasonably complete data exist only in a few cases of industrial importance where considerable lengths of pipeline are involved, for example in the hydraulic transport of coal,[5, 6] the transport of sand and gravel in dredging and land reclamation, the flow of liquid mud in oil drilling operation,[7] and also the pneumatic transport of cement, corn, etc.

Pipelines and piping carrying solids suspended in a liquid or a gas must be of the simplest type so that the flow conditions are as uniform as possible throughout the system. When the flow direction changes and eddies are formed, such as pipe bends and valves which are not full bore, the

material may precipitate out. In such systems it is most important to keep the fluid flowing at a rate below a specified minimum, since once it has stopped or its velocity has been reduced and the solids separate out, it may be extremely difficult to bring the system into operation again.

The abrasive properties of the particles in the fluid and their effect on the life of the pipeline generally call for straight runs of piping and, wherever this is not possible, easy replacement of bends or their reinforcement, either with extra metal thickness or with tough, resilient, rubber linings, is advisable.

(**b**) **Chemical properties.** The chemical properties of the fluid determine:

(i) The aggressivity to various possible materials of construction.
(ii) Certain safety aspects governed by inflammability and toxicity in the case of leaks and possibly radioactivity.

Since steel and cast iron are by far the cheapest of the commonly used metals of construction, they are first choice where the fluids are only very slightly aggressive. For fluids which are aggressive towards steel, the choice lies between:

(*a*) Steel surfaces coated with paint of various types, sprayed metal and plastic coatings, linings of plastic and rubber.
(*b*) Mild steel clad with a layer of a more resistant and more expensive metal, such as stainless steel or nickel. The reduction in the price of clad metal pipe over pipes of resistive metal alone is to some extent offset by the increased cost of fabricating clad metal.
(*c*) A chemical-resistive metal—both aluminium and stainless have been used for buried pipelines of appreciable length.
(*d*) A non-metal, such as cement, pre-stressed concrete, asbestos cement, glazed or unglazed earthenware, or any of the wide range of plastics and fibre-reinforced plastics which are available as pipes.

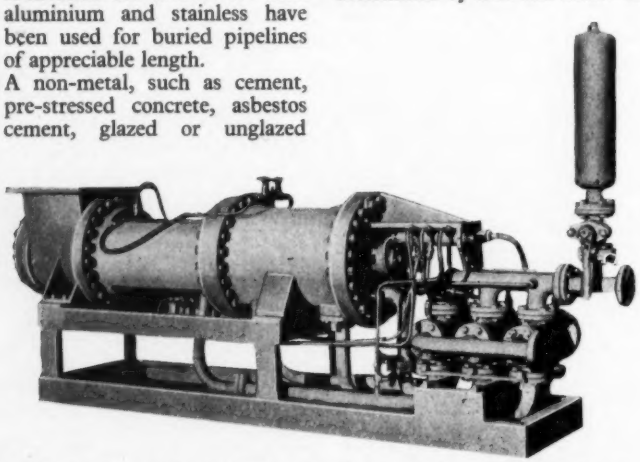
Where the material is dangerous, greater care must be taken to ensure that the possibility of leaks occurring is reduced to a minimum—the line should be sectionalised so that a severe leak or burst can be limited to a relatively short section of the line, etc. When radioactive materials are being pumped, special measures must be taken to avoid the possibility of leaks into surrounding soil.

(ii) Transference of fluid

The first factor to be considered is whether there exists between the point at which the fluid is available and the point to which it must be transported a positive hydraulic head of appreciable magnitude. If the loss of head, when the fluid flows at the required rate along a line of practicable and economical size, is less than the available static head, then no additional pumping may be necessary. It must be ascertained that hydraulic conditions at every part of the line are satisfactory. It is important to remember that the rate of flow may vary appreciably with temperature (due to viscosity variation) and the rate of flow for the lowest possible temperature, and a friction factor for the pipe which might develop after a few years of operation should be used for design purposes.

If the static head is insufficient, then a pump or pumps must be employed to give the required rate of flow. The economic balance between high pumping pressure with small line diameter, and low pumping pressure with large line diameter must be determined by trial and error. Economic line diameters normally give liquid velocities of 5 to 15 ft./sec. and this reduces the range of the trial calculations. The selection of the best pumping equipment for any service is very largely a matter of experience. Factors to be considered are the type of cleanliness of the fluid to be pumped, its viscosity (and possibly the range of viscosity), whether the plant is to run intermittently or continuously, and the (type of) power available for driving the pump.

In general, it can be stated that fluids of low viscosity can be effectively handled by centrifugal pumps, and the higher viscosity fluids by positive rotary pumps, such as the *Plenty* pump, the screw type, or the piston type of pump, an interesting development of which is the *Meader* pump, illustrated here, for handling very viscous fluids or fluids with a high solids content.



'Meader' pump for handling very viscous fluids, mentioned above.

Prime movers which have been used for pumps for pipelines service include piston and turbine steam engines, electric motors, low- and high-speed diesel engines with and without turbo-charging, petrol and natural gas engines, gas turbines, and free piston engines.

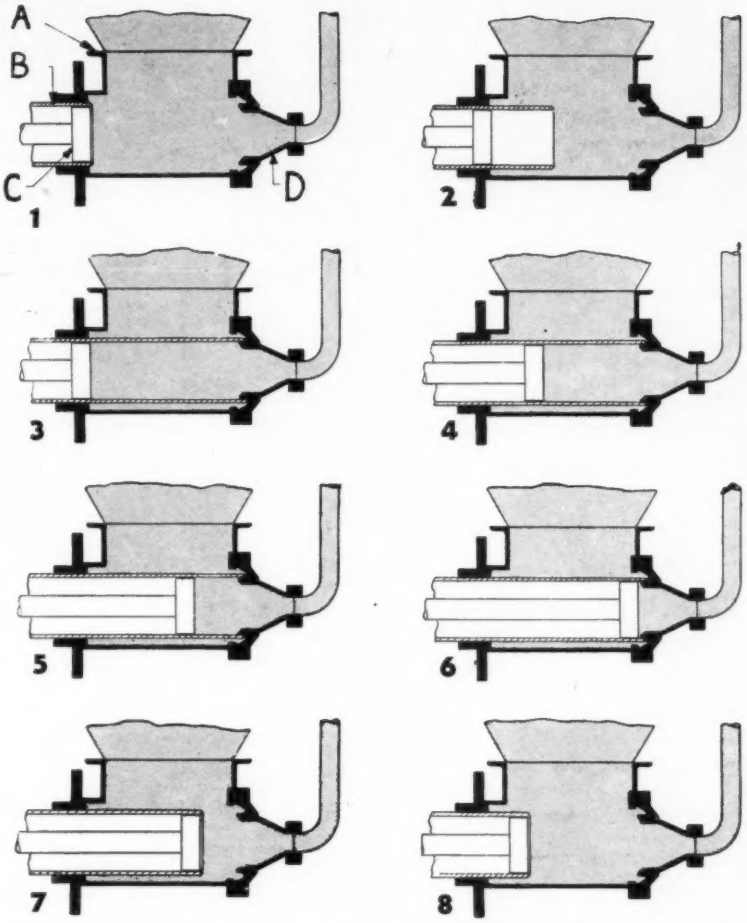
(iii) Overall piping scheme

Fluids may be transported in pipelines carried either above or below ground. The selection of the method to be employed depends upon a variety of circumstances.

Overground pipes are likely to be preferable where there is a complexity of piping and the distances are short, when the lines are thermally insulated, and when easy access is necessary for inspection and maintenance.

For long pipelines which are laid outside the confines of the plant or works, it is normally necessary to put the pipe underground in order to avoid interference with surface activities.

(**a**) **Overground pipes.** When overground piping is being designed, the support of the piping and the regulation of its movement are of importance in order to prevent thermal, gravitational and other forces building up to the point at which the material of the pipe is overstressed and deformed, or points of anchorage are moved. The initial step in the design of an overhead pipeline is to determine from plant data which points of the line must remain fixed, *e.g.* the points at which it is flanged into a pump or vessel or other fixed item of plant. The piping should then be designed so that only the minimum



Sequence of operation of the 'Meader' pump: (1) the chamber is loaded with material; (2) and (3) the cutting cylinder forces its way into the material; (4), (5) and (6) the ram forces the material from the cylinder into the discharge pipe; (7) and (8) cylinder and ram together are withdrawn and further material falls to bottom of chamber. In diagram (1), A represents the mud hopper, B, the cutting cylinder, C, the ram, and D the outlet cone.

stresses are applied to these points. A method of stress analysis is given in the literature.[8] The pipe may be supported either by hangers from above or on transverse beams or structures supported from below.

When hanging supports are used, the ground beneath the piping can be kept clear and the supports can be sprung so as to give additional resilience to the piping. Unless there is some special design reason for using hangers, it is usual to rest the pipe on supports near the ground, since this method is less costly. The relative movement between the pipe and the structure on which it rests may cause wear of the pipes, and padding or reinforcement of points of contact is often desirable.

The spacing of hanging supports is determined by the structural strength of the pipeline (including joints), the need for maintaining the correct slope on the line at all points to allow for proper drainage and the availability of support positions.

As an indication of the considerable variation in the spacing of supports, it can be taken that a thin-wall, 6-in.-diam., mild-steel pipe might be supported at intervals of between 20 to 30 ft., whereas a 6-in.-diam. polythene pipe should be supported along its entire length and, in any event, the spacing of the supports must not exceed 4 ft.

(b) **Buried pipes.** For a buried pipe the problems of stressing are much less acute, by reason of the continuous support and restraint given to the pipe by the soil surrounding it. The frictional forces between the pipe and the soil tend to damp out any oscillations of the pipe, which might be of considerable magnitude in an equal length of similar pipe above ground. There is, of course, a structural difference between flanged or welded steel pipes (which have an almost uniform strength along their length) and pipes which have spigot and socket packed joints which will not take any tensile stress and consequently must not be subjected to transverse thrusts. At changes in the pipeline alignment the stresses are taken up by concrete anchor blocks.

The corrosivity of some soils (especially those in the vicinity of chemical plants) to cast iron and steel may be high and at such locations it is desirable to coat the pipes with suitable materials such as:

(i) A bituminous or coal-tar-derived enamel which may be reinforced either with asbestos fibres or *Fibreglass*.

(ii) A tape or bandage impregnated with a soft, inert petroleum compound.

(iii) A self-adhesive tape of a plastic material such as PVC or polythene.

Steel pipes which carry liquids of a mildly corrosive nature such as seawater (for cooling purposes) have been bitumen- or cement-lined to increase their life.

Cathodic protection has been applied to the external surface of all types of buried cast-iron and steel pipelines. It has also been applied for the protection of the internal surface of cooling water mains.

Pipeline ancillaries

Valves. Main-line valves are installed for three reasons: firstly, to direct the flow; secondly, to regulate the flow of fluid along the line by throttling (they may be operated by hand or by motor, driven by electricity, air or hydraulic fluid); and, thirdly, to isolate sections of the line in case of bursts or leakage, or in order that pressure testing may be carried out over short sections. Other valves such as swing-check valves, pressure-reducing valves, etc., are also used. Block valves should introduce as little pressure drop into the line as possible and, when the line is to be cleaned internally by 'pigging,' it is essential that the valves are full-bore. Small-valved branch lines are required at the low points of the line to permit

(*Concluded on page* 405)

Lagging Improvements in a Heavy Chemical Works

By R. A. Duckworth
(*Works Engineer, F. W. Berk & Co. Ltd.*)

HOW many lagging specifications for external work conclude with 'two layers of bitumenised roofing felt securely wired on with chicken wire and painted two coats of black varnish to complete'?

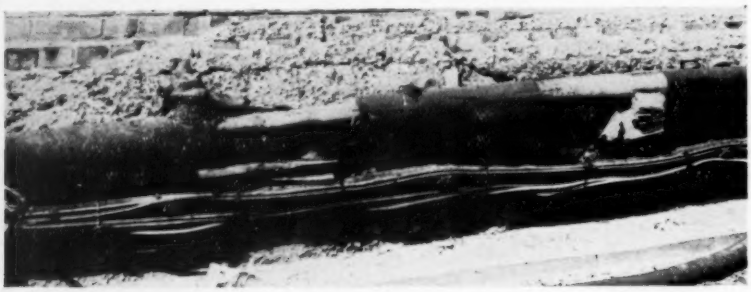
In a chemical works the chicken wire soon corrodes and the felt flaps dismally in the wind, rain soaks the lagging, and eventually the pipe corrodes unnoticed (Fig. 1).

The following specifications are the result of efforts made in the writer's factory to overcome this problem. They reduce the amount of corrodible wire to a minimum, and maintenance costs have fallen almost to zero. The finished lagging has a neat and trim appearance (Fig. 2), is externally watertight and, although initial cost is greater, this is more than balanced out by the longer life obtained on both lagging and pipework.

Steam lines

Internal. One-inch-thick 100% pure asbestos or 85% magnesia preformed sectional insulation, securely finished with white cotton sheeting with overlaps firmly pasted down, painted with two coats of emulsion paint to an approved colour with aluminium bands fitted externally at 18-in. centres; 4 to 6 in.: $1\frac{1}{2}$-in. thick.

External. One-inch-thick 100% pure asbestos or 85% magnesia preformed sectional insulation, securely finished with white cotton sheeting with overlaps firmly pasted down, weatherproofed with one layer of single-ply roofing felt secured with one layer of 0.006-in. PVC adhesive tape, 3-in. wide, spirally wrapped with 1-in. overlap, and fitted with PVC tape colour bands at 10-ft. intervals; 4 to 6 in.: $1\frac{1}{2}$-in. thick.



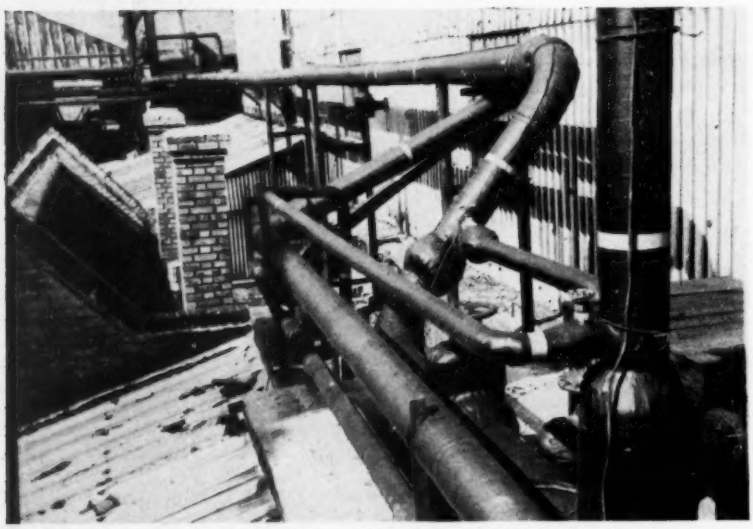


Fig. 1 (*above*). **Deteriorated lagging of bitumenised roofing felt and chicken wire, revealing corroding pipe.**

Fig. 2 (*below*). **PVC-covered lagging using a minimum of wiring, with tape colour bands at 10-ft. intervals.**

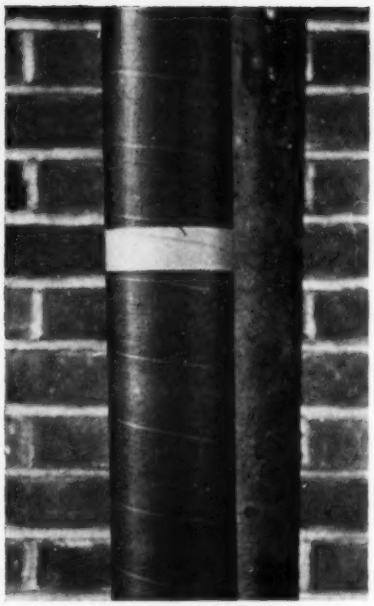


Fig. 3. Close-up of PVC-taped line.

Hot water, cold water and acid pipes

Internal. One-inch-thick *Econite* compressed wool felt sectional insulation, secured by non-corrodible staples, finished with white cotton sheeting with overlaps firmly pasted down and finally painted with two coats of emulsion paint to an approved colour.

Hot-water pipes, external. One-inch-thick *Econite* compressed wool felt sectional insulation, secured by non-corrodible staples, finished with white cotton sheeting with overlaps firmly pasted down, weatherproofed with one layer of single-ply roofing felt secured with one layer 0.006-in.-thick black PVC adhesive tape, 3-in. wide, spirally wrapped with 1-in. overlap, and fitted with PVC tape colour bands at 10-ft. intervals.

Cold-water and acid pipes, external. To be covered with 1-in.-thick hair felt applied in two layers, securely wired on and protected with one layer of single-ply roofing felt secured with one layer of 0.006-in.-thick black PVC adhesive tape, 3-in. wide, spirally wrapped with 1-in. overlap, and fitted with PVC tape colour bands at 10-ft. intervals.

Taping technique

A 4-in. clearance round pipe flanges must be maintained on taped lines, otherwise poor workmanship is an inevitable result. Lapping of the tape must always be against the weather to prevent rain penetration. The PVC tape used to date has been supplied by Smith & Nephew, and is black. Indication of the contents of pipes is by means of coloured tape bands at 10-ft. intervals. Kitsons Insulations Ltd. co-operated with the writer in the various trials which established this specification, and their workmen have now developed a skill in taping which enhances the workmanlike appearance of the pipelines, arising from the trim glossy tape, which does not degrade under weathering (Fig. 3).

The taped lines stand up well to general mis-use from the ends of ladders, and from hob-nailed boots. The PVC tape provides good protection against acid fumes and spillage. After twelve months no visible deterioration has taken place, and there seems no reason why the life of the taped lagging should not be thought of in terms of a number of years.

The author thanks Mr. F. A. Rivett, works director, F. W. Berk & Co., for permission to publish this note and for use of the photographs.

Pipeline in Glass

By J. McN. Bruce, A.M.I.Chem.E.
(*Technical Director, Q.V.F. Ltd.*)

This article briefly outlines some of the salient features of glass pipeline, with some comments on design, installation and maintenance.

IT is probably true to say that the pipe, definable as a device for the conveyance of fluids, has done more to aid man's useful employment of natural resources than any other single contrivance. The development of piping from the hollowed-out logs used by our forefathers to the complex and versatile range of pipes now freely available in many materials is an interesting example of engineering evolution. Among the specialised types in everyday use glass pipeline is of particular interest to the chemical or process engineer and some aspects of its application will be discussed here.

The above definition of a pipe as a conveyance for fluid leads naturally enough to consideration of capacity, pressures and other purely mechanical features but, when the fluid which is to be handled is specified, attention is directed to the material of construction. In most instances the employment of glass as a material for pipeline construction results from its singular chemical stability and resistance to corrosion. Two broad types of application are encountered, the first being the conveyance of fluids which are strongly corrosive and which significantly reduce the wall section of pipes in materials other than glass in a short time. This is typified by the handling of hydrochloric, nitric and sulphuric acids.

Secondly, many liquids which are not strongly corrosive but which pick up small traces of the pipeline material, and are thus rendered unsuitable for their intended use, may be handled in glass lines without so doing. Of this category typical examples are found in breweries, distilleries and dairies.

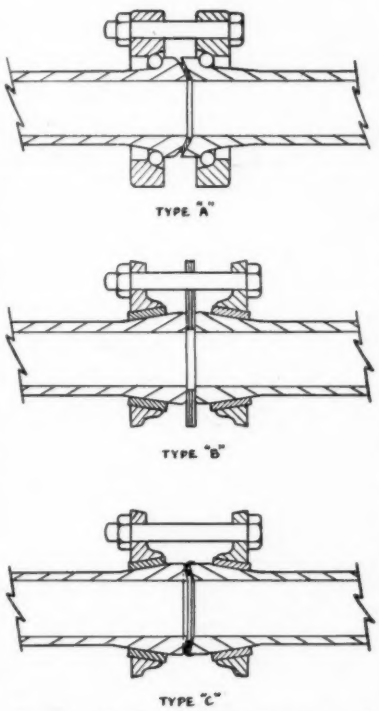


Fig. 1. Three alternative types of coupling for glass pipeline.

Properties of glass pipeline

Glass pipeline and fittings are generally fabricated in a borosilicate glass which, in addition to exceptional corrosion resistance, has a low value of thermal expansion coefficient and is thus of high thermal endurance, or resistant to thermal shock. Such a glass is resistant to most mineral acids at the temperatures and concentrations normally encountered industrially, notable exceptions being hot, concentrated phosphoric acid and hydrofluoric acid. The latter reagent attacks the silicates of which glass is largely composed and causes rapid failure. Caustic alkalis also attack glass, the rate of penetration depending to some extent on concentration but to a more marked degree on temperature.

Whilst it possesses very favourable properties from the corrosion resistance point of view, glass has physical characteristics which call for special attention when the mechanical design of glass structures is considered and its successful use depends on an appreciation of these qualities. Glass has no clearly defined tensile strength and the calculation of safe loading conditions is done on a statistical basis. Glasses have a mean value for tensile strength of approximately 10,000 p.s.i. and this appears to be independent of composition. For pipeline work it is usual to limit stress on the material to a figure of 500 to 1,000 p.s.i., the lower value being

that on which internal pressure ratings for glass pipeline are based. When stressed in compression, on the other hand, glass is almost unbreakable and it is known that breakage of glass invariably occurs due to limiting tensile stress in a surface.

Joining glass pipes

With these facts in mind it is clear that, when designing closures or joints in glass pipe or other types of glassware, the desirable system is one which imposes a minimum of tensile stress on the glass. In practice, the shapes which are employed to couple glass pipe sections are such that the joint compression necessary for leak-tight closure is applied through tapered or similarly shaped buttresses rather than through flat flanges with their high bending and tensile stress components.

Fig. 1 details three types of glass pipeline coupling, all of which are in widespread use. Type A has a compound conical buttress end with spherical mating faces and is assembled with an interface gasket and insert of circular section and recessed backing flanges. The necessary joint compression is provided by bolts and nuts through holes in the backing flanges. Type B combines a simple frustro-conical buttress with flat ground faces, gasket, rectangular section inserts and conical bore backing flanges. The frustro-conical buttresses and spherical mating faces are combined in type C which, in common with type A, allows a few degrees of axial misalignment to be accommodated.

Glass pipeline and fittings having buttress ends of type B are the subject of a British Standard Specification, B.S. 2598 : 1955, and are available in sizes ranging from $\frac{5}{8}$ to 18-in. bore.

Mechanical considerations

The factors which control the design of the individual items in a glass pipeline installation must also be considered in relation to the layout and support of the system. The loads involved must be carried so that the glass is stressed in compression or, where this is not possible, so that the tensile components are kept to a minimum. Glass pipeline should be supported adequately on hangers or brackets provided with adjustment to enable adjacent sections to be brought into accurate register, with flange faces parallel, before joints are closed. Expansion effects should be estimated and provision made to accommodate growth. The thermal expansion of glass pipeline is in the order of one-third to a quarter that of steel pipe but, where long runs are involved and high temperatures are specified, it may be necessary to design in flexibility by using right-angled bends or expansion bellows.

Fig. 2. Glass pipeline installation with adjustable hangers.

The disposition of support points on a glass pipeline layout depends on the density of the fluid handled and Table 1 details the maximum unsupported span lengths for glass pipeline as a function of pipe bore and contents density. These values are based on the imposition of a maximum stress in the pipe wall due to dead weight of pipe and contents of 500 p.s.i. Minimum permissible wall thickness has been assumed and the stresses are calculated as for a simply supported beam. Fig. 2 shows a typical glass pipeline installation and clearly illustrates the adjustable hanger type of support used in this class of work.

Table 1. Estimated Maximum Unsupported Span Lengths for Glass Pipeline

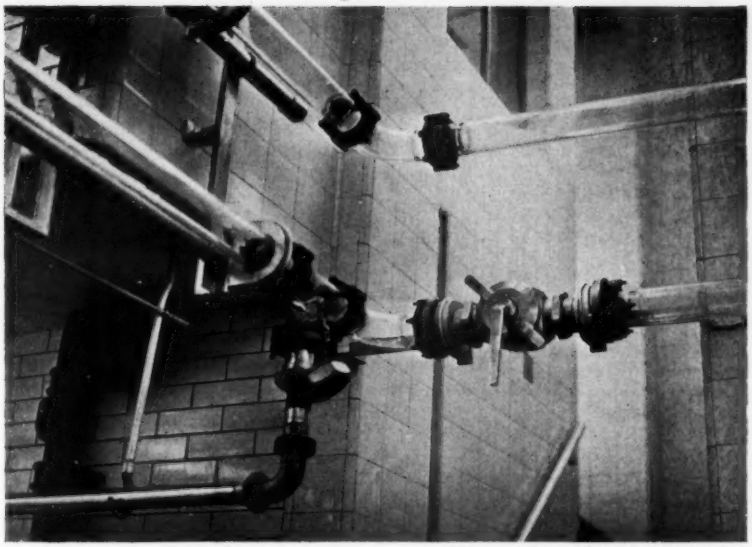
Pipe bore in.	*Air or gas ft.*	*Water* S.G.1.0 *ft.*	*Acid* S.G.1.8 *ft.*
$\frac{3}{8}$	7	5	4
1	8	6	5
$1\frac{1}{2}$	10	7	6
2	12	7	6
3	15	8	7
4	17	9	7

Where valves are installed in glass pipeline it is necessary that they be supported independently of the pipe, in such a manner that the moments generated on operation of the valves are not transmitted to the glass. Fig. 3 shows a large diaphragm valve controlling flow in a glass line and illustrates this point. Fig. 4 includes a steel plug-cock, clipped to a support bracket, providing both anchorage for the fairly heavy steel item and satisfactory support for the associated glass pipeline.

Economics of glass pipeline

In addition to the purely technical and operational factors which have been discussed very briefly above, the economics of glass pipeline are of interest to potential users. It is probable that glass will be compared with one or other of the nickel chromium alloy steels when possible applications are under review and there is no doubt that it is strongly competitive in this field. Apart from first cost, however, the singular chemical endurance of glass implies a low depreciation rate which, provided the pipeline is

Fig. 3. Diaphragm valve supported independently of glass pipeline.



[*Courtesy: Express Dairy Co. (London) Ltd.*

Fig. 4. Steel plug-cock and glass pipe, showing method of support.

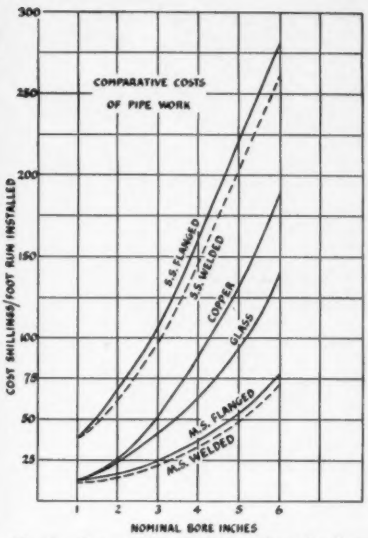


Fig. 5. Comparison of costs for pipeline in different materials.

properly installed and maintained, will often justify its selection against an alternative material of lower first cost but shorter working life.

The conditions under which pipeline has to be installed are subject to such wide variation that cost data in absolute terms are of doubtful value. Fig. 5 shows the comparative costs of pipeline in various materials in terms of foot run installed and pipe size.

Maintenance

The maintenance of glass pipeline involves little more than occasional cleaning, which is readily carried out *in situ*, and periodically the renewal of gaskets.

Where glass pipe is installed in particularly corrosive atmospheres, the bolting and the backing flanges may also require renewal from time to time, but these are a relatively small part of the cost of a glass pipeline installation and the main items will, apart from mechanical breakage, last indefinitely.

To sum up, glass offers to the process engineer a pipeline material capable of meeting a wide range of corrosive duties and one which is competitive in price with those materials likely to be considered as alternatives.

Factors in the Design of Pipeline Systems

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drainage and at high points to allow venting of air.

Heating of pipeline fluid. Heating of the fluid flowing along a pipeline can be achieved by three different methods: internal tracing, external tracing and by generating heat electrically in the wall of the pipe.

Internal and external tracing can be carried out by small-bore steam pipes, or by electric heating cables specially designed for the purpose which have a specified heat output per unit of length. The design of steam tracers is complicated by the need to make provision for water disposal at fairly frequent intervals and to ensure drainage of the tracing lines to these points. When heating is achieved by passing an electric current along the wall of the pipe, large currents at low voltage are required and sections of the line must be electrically insulated.

Lagging. To conserve the heat (or the 'cold') of the fluid the line may be wrapped with a thermal insulant such as:

(*a*) A magnesia / asbestos material which is placed on the pipeline as a semi-fluid mass which is moulded to the pipe and allowed to set.

(*b*) Cork, *Fibreglass*, *Rocksil* or expanded plastic which is supplied in preformed sections suitable for the diameter of the pipe to be insulated.

(*c*) Corrugated aluminium foil.

(*d*) Cellular concrete.

Since the thermal resistance of these materials is dependent largely on the existence of air spaces within them, it is most important that the insulant be kept completely dry, and achieving this is one of the major design problems and the reason why lagged lines are not buried unless it is essential for other reasons. Various forms of waterproof covering are placed around the insulant and efforts made to seal this covering completely.

There are, of course, numerous other matters connected with pipelines, such as process control equipment, automatic valving, and special fittings, but space does not permit a discussion of these, nor does it allow elaboration of the information on design.

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Pipeline Welding Techniques

By P. Trippe

Without modern welding techniques, many of them developed specially for the chemical and process industries, these industries as we know them today could never have evolved, and it is in the lines of communication—the pipelines—that welding has made one of its most significant contributions. This article describes the latest techniques.

IT is still the tendency amongst many unfamiliar with the refinements of modern welding techniques to consider that welding is a somewhat coarse and unprecise procedure. This outlook fortunately is becoming increasingly rare. It is indisputable that the vast majority of bad welds are the product either of insufficient knowledge of what welding can, and cannot do, or of careless practice. A designer may be involved in a costly construction which, had he been more familiar with welding techniques, could have been fabricated at considerably lower cost. Conversely, many a designer has brought trouble on his own head—for which he is liable to blame either the welding engineers or the welding operators—for the simple reason that he has positioned joints that are inaccessible or, at best, very much more difficult to weld than they need have been. Some examples will be given later.

Pipe fabrication

This article deals in the main with pipe fabrication, because it is a major application for welding in the chemical processing industry. Apart from pipelines, storage tanks and pressure vessels also come broadly into this category.

There are three main manual welding processes: gas welding by oxy-acetylene flame; metallic arc welding using a consumable covered electrode; and shielded arc methods, such as the *Argonarc* process in which a non-consumable tungsten electrode is employed. Various automatic methods are in use, and these also fall into three general categories: the submerged arc method, such as the *Unionmelt* process; open arc methods characterised by the *Fusarc* and *Fusarc*/CO_2 methods; and self-adjusting arc processes, of which the *Sigma* system is an example.

The submerged arc method protects the molten weld metal by a layer of granulated flux. It has a number of advantages apart from ensuring that the weld metal is free from contamination. There is no loss from spatter or vaporisation, high welding currents can be used, and distortion is minimised. As the arc takes place under a blanket of protective flux, it is not visible to the operator, so that the usual protective visors and so on are unnecessary.

The open arc method uses either a continuous flux covered electrode or, in addition, a shield of CO_2 to protect the weld. Fast welding speeds and high-quality weld metal are features of the latter process.

Shielded inert gas metallic arc (*Sigma*) welding has been developed largely for light alloys but is also used extensively for welding copper and its alloys, stainless steel, and more recently a suitable wire has been developed for mild steel. With this method a bare wire is fed into the arc at a constant speed, the molten weld metal being protected by argon gas in the case of non-ferrous metals and argon/oxygen mixtures in the case of stainless steel and mild steel. Two types of equipment are available, a fully automatic version and a semi-automatic method utilising a pistol gun. The latter type has recently become available in a new improved form known as the Quasi-Arc *Lynx* equipment.

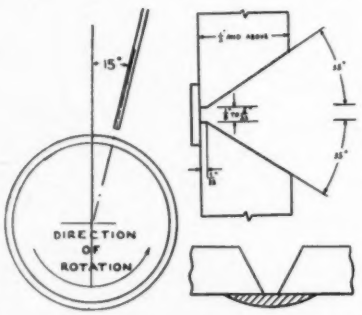


Fig. 1. Conventional pipeline welding technique uses the type of preparation seen here, with the welder working upwards on the joint, from bottom to top. A more advanced technique is downward, or stovepipe, welding, using special electrodes. Weld is made from top to bottom. It requires more skill but is much faster.

The *Argonarc* process, also available in manual or automatic form, uses a tungsten electrode and a bare wire shielded by an inert gas. Argon is normally used in this country; in the U.S.A., helium is sometimes used.

The majority of applications in the chemical processing industry are met by the manual metallic arc, and automatic shielded arc methods. Manual welding using covered electrodes is still in general use for pipeline work, although there are significant developments in this direction which will be described in greater detail later. Automatic welding is largely confined to larger pipes and vessels.

Work in the shop if possible

The different requirements of shop fabrication and site fabrication are not always fully appreciated. As a general rule, larger pipes and vessels are fabricated in the shop, whereas pipelines are done on site. It should be remembered always, though, that work carried out on site puts the welder at a disadvantage. For example, pipes on site are normally fixed and, as yet, there is no process which can carry out welding on cylindrical sections automatically unless the pipe can be rotated in a suitable manipulator, so that manual welding is inevitable. There are, however, methods by which this can be minimised, and mention is made of some of them when automatic techniques are considered in greater detail.

Techniques for joining pipes on site fall into two main categories—the joint can either be made by welding on flanges and making a bolted connection or it can be butt-welded. Of these, butt-welding only will be considered here, as it is the method employed almost universally in this particular context.

Methods and snags on pipework

Various methods have been developed for butt-welding pipe, but in all of them accurate preparation of the pipe ends is of primary importance. Some typical arrangements are shown in Fig. 1. The main problem is to achieve a sound root bead which will not penetrate into the inside of the tube in such a way that it causes obstruction or becomes vulnerable to corrosion from the material flowing through the pipe.

Backing-ring technique

The backing-ring technique has been a standard method of butt-welding pipes for many years. It is thus well established, and comprises the use of a backing ring of a design which prevents rigid restraint after welding and, when the weld is correctly applied, results in a smoothly curving section, as seen in the diagram. However, in the petroleum industry in particular and the chemical industry in general, it only has limited application. For much petroleum work the corrosion danger makes it impractical, as the backing ring cannot be machined out after welding. In chemical plants the technique is employed only in power station applications or in runs where no solids or chemical liquids are passing.

Unbacked butts

By far the largest amount of butt-welding in the industry is carried out without the use of backing rings. This method is used on pipes down to 4 in. diam., manually, or about 16 in. diam. and above where there are facilities for automatic welding.

In manual welding where the joint cannot be rotated the following two methods are in general use on unbacked joints:

(1) Welding in a downwards direction, *i.e.* 12 o'clock to 6 o'clock, using cellulose electrodes (B.S. 1719, Class 1XX).

(2) Welding in an upward direction, *i.e.* 6 o'clock to 12 o'clock, using rutile electrodes (B.S. 1719, Class 3XX).

The welding techniques and edge preparations employed are quite different for the two methods and these are now considered in detail.

The upward method

Because of the low currents necessary to maintain control over the molten weld metal when welding upwards, slower electrode burn-off rates are obtained. This, together with the greater build-up of weld metal, results in this method being considerably slower than the downward technique where high welding currents result in fast electrode burn-off rate and travel speed.

However, in spite of being slower, the upward method is widely used and possesses certain advantages in those instances where it is not always possible to get accurate fit up of the joint.

The main difficulty in welding unbacked pipe joints by the upward method lies in obtaining a root run that is free from elongated gas holes. This phenomena, usually referred to as 'piping,' is caused by contamination of the molten weld metal by the atmosphere (Fig. 2).

Research into this problem has shown that certain practical steps can be taken to avoid 'piping' and the most important of these is correct setting of the root gap.

If the gap is too small the flow of shielding gas, generated by components in the electrode coating, cannot flow freely through to protect the reverse side of the weld bead.

The best results are obtained with a root gap of $\frac{5}{32}$ in. using a 12 s.w.g. electrode. As a general rule the gap should not be less than $\frac{1}{8}$ in. and the electrode diameter should not exceed 10 s.w.g. if 'piping' is to be avoided.

Once a satisfactory root run has been obtained, no difficulty will be experienced in completing the joint using normal vertical upward welding techniques and the jobs may be speeded up by using either 8 s.w.g. or 6 s.w.g. electrodes, the size depending on the wall thickness of the pipe.

'Stovepipe' technique offers advantages

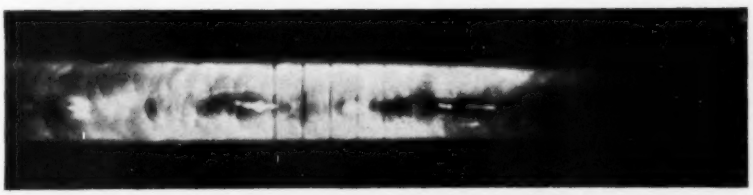
The butt-welding methods described above use the upward technique—that is, the operator starts at the bottom of the weld, as the diagram shows, and works upward. Now, the direction in which the weld is made has a very considerable effect on the formation which the weld takes, due to the effect of gravity on the molten weld metal and other considerations.

There are thus two possible approaches to laying down the root bead—and it is the quality of this bead on which the whole efficiency of the weld depends, and each will produce its own characteristic weld pattern. The downward technique was developed in the U.S.A., where it is known as 'stovepipe' welding. It requires considerable manipulative skill on the part of the operator, and there are more passes than in upward welding, but it can be considerably faster. The technique has been further improved by the introduction recently of special electrodes.

The skill is in laying the root pass or stringer bead. It is deposited with an 8- or 10-gauge electrode, the operator pressing hard into the joint. Technically this is known as a tight 'drag-welding' or 'touch-welding' technique. The electrode is held at an angle of approximately 60° at the start of a downward pass. Immediately after laying the stringer bead, a second run, known as a 'hot pass' because it is done while the metal in the joint is still warm, is deposited, using less pressure. The third run puts in the filler bead, followed by a 'capping bead' to complete the weld.

The effect of the high pressure applied to the electrode by the operator is that more arc is produced on the inside of the joint, in depositing the stringer bead, than on the outside, so that the arc spreads round the wall and results in an even and smoothly graded internal weld section.

The form of the two ends to be butt-welded is, in general, similar to that already described for upward welding,



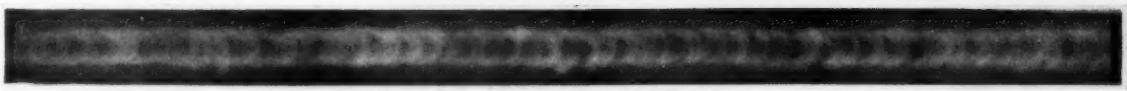


Fig. 2 (*right*). **Typical 'piping' condition is seen in this radiograph.**

Fig. 3. Radiograph showing a butt weld on $\frac{1}{2}$-in.-thick plate, with edges prepared to a 60° double vee, using a 'Celtian' electrode. This radiograph is particularly good, but results like this can be obtained consistently by using the downward method and this type of electrode.

but there are important variations in the gap at the root. Work prepared for one of the techniques would not be ideal for the other. It is therefore necessary to consider the relative economies of each method in relation to the welding skill available, and determine in advance which preparation shall be used.

Even a skilled welder has to learn the technique if he has not used it before, and the downward method also has the disadvantage that the standard of preparation must be higher.

Main application at present is on long transmission lines, where a team can be used, with the first operator working on the stringer pass, a second following-up with the 'hot' pass, and the third operator making the filler pass. Where necessary operators can work on each joint in pairs, *i.e.* they each weld half of the pass.

Downward technique reduces piping

The shape of pool formed in downward welding does much to eliminate piping since a narrower pool is formed, and freezing takes place more rapidly. There is thus less likelihood for a gas inclusion to spread through previous beads and produce the characteristic elongated cavity. In upward welding it may involve the additional, and laborious, operation of chipping the first pass, to ensure that all 'wormholes' are removed, and then making another pass over it.

Another technique which is sometimes used is to lay the root pass by gas welding methods. The *Argonarc* process has also been used successfully for the root pass. Alternatively a consumable backing ring can be used, but this is a more expensive method and is slow to prepare. A variation of the *Argonarc* process introduces the inert gas into the inside of the pipe. A simple way of doing this is to use small balloons at each open end, which seal the portion under welding quite adequately to ensure flow of gas on to the joint without uneconomical leakages.

Special electrodes eliminate problem

A major development is electrodes specially designed for the general fabrication of mild steel, and particularly applicable to site welding of tanks, vessels, and pipelines. Known as *Celtian*, this type of electrode is fully extruded with a cellulose-type covering, but with the difference over normal cellulose-covered electrodes that iron powder is included in the covering. It can obviate 'wormholing' altogether and has a number of other important advantages.

A larger volume of weld metal can be deposited in the same welding time as compared with conventional cellulosic types. Thus, it offers considerably increased welding speed and an appreciable saving in overall costs. The *Celtian* electrode gives very stable arc conditions and can in fact be used with alternating current, whilst conventional types must be used with direct current.

There is the additional advantage that, apart from pipe-welding, it eliminates the need for back chipping on vertical welds for butt joints on tanks and vessels. Previously, it has been necessary with the upward method to chip out much of the root bead from the rear in order to get rid of 'wormholing' and then make another pass from the rear; this is obviously a very time-consuming process. With the newer electrode, it is only necessary to lightly brush the penetration bead before applying the sealing run. Further, better penetration is obtained. The technique is recommended for plates up to $\frac{1}{2}$ in. thick.

On average, downward techniques are two to three times as fast overall as upward methods, and this figure is improved even further by the use of the specially-developed electrodes.

The development of 'stovepipe' techniques with cellulose-iron powder covered electrodes is one of the most important developments of recent years to any industry faced with the problem of pipe-welding and welding fabrications where the advantages of vertical downward technique can be used. The weld also offers considerably easier application under adverse site conditions, particularly where there are heavy winds. The radiographic results obtained are of a very high order.

Saving time in the field

One method of reducing site welding of pipe butt joints is to join two lengths of pipe together in pairs. This may be carried out either in the shop or at some temporary centre set up, and if necessary moved periodically as pipe laying progresses. Such procedures are only warranted where the pipeline is a long one, and to achieve maximum speed and economy automatic welding methods must be used. This technique has been widely practised in the United States and abroad, and is commonly referred to as 'double ending' or 'double lengthening.' It is necessary to put the stringer bead in manually first, the pipes are then moved to the automatic welding station, where they are rotated during welding by a specially designed roller bed. Automatic 'double ending' is likely to become a more attractive proposition by the introduction of new equipment by Quasi-Arc Ltd. This equipment can use any of the automatic welding processes including *Fusarc*, *Fusarc*/CO_2 or *Unionmelt* and incorporates a number of attractive features for the rapid and accurate positioning of pipes under the automatic welding head. Where mains power is not available, the new Quasi-Arc design can include engine-driven equipment, providing power for the

Table I. Relative Costs of Butt-welding 18-in. o.d. × $\frac{3}{8}$-in. Pipe

(Assume labour at 7s. 6d. per hr. and overheads at 200% of labour)

	Arcing Time	*Electrode cost*	*Labour cost*	*Overheads*	*Total cost per joint*
		s. d.	Assume 25% duty cycle:	s. d.	s. d.
Welding upwards, *i.e.* 6 to 12 o'clock, using *Vordian* (B.S. 1719, Class 3XX) manual electrodes	35 min.	1 10	17s. 6d.	35 0	54 4
Welding downwards, *i.e.* 'stovepipe' technique using *Celtian* (B.S. 1719, Class 1XX) manual electrodes ..	20 min.	1 5	Assume 33⅓% duty cycle: 7s. 6d.	15 0	23 11
Welding stringer bead by manual 'stovepipe' technique followed by *Fusarc*/CO_2 automatic welding	Manual welding: 3 min. 30 sec. Automatic welding: 8 min. 50 sec. Total: 12 min. 20 sec.	Manual: 3 Automatic: 1 8 Total: 1 11	Assume 40% duty cycle: 3s. 11d.	7 10	13 8

welding head and roller bed, so that the complete installation can operate independently in remote country districts, desert areas, etc.

Methods of welding special steels

Apart from pipe and vessel welding, there are many applications in the chemical processing industry where special steels have to be welded. There is not space here to describe techniques in detail, but virtually all contingencies are covered, and there is an extensive range of electrodes suitable for each group of materials.

Creep-resisting steels can be welded satisfactorily, provided the correct electrode is chosen to suit the material and the correct pre-heat and post-heat treatment is used. For stainless and heat-resisting steels, the *Argonarc* process is sometimes used for the root pass of pipe joints, and completed by manual arc welding. It is essential that the electrode, once again, should match the plate material, and in the case of the 18 Cr-8 Ni series, the weld metal must be stabilised to prevent subsequent weld decay. Weld decay is prevented by balanced additions of niobium in the electrode, to provide an element which will form carbides in preference to chromium. In effect, a carbide is formed preferentially with the stabiliser rather than with the chromium in the alloy.

Acid-resistant steels require a molybdenum-bearing weld metal and certain electrodes also have stabilisers to prevent weld decay. A major problem in welding of fully austenitic stainless steels is the avoidance of micro-cracks. A comparatively new electrode, *Chromoid* 5, has been specially developed with high resistance to micro cracking, and at the same time the ferrite content is controlled below 0.5%. This low order of ferrite is essential for high-temperature service and high resistance to corrosion. In addition, it avoids the necessity for post-heat treatment in welding the low alloy creep-resisting steels—a very useful property since fabrications of these steels on site makes post-heat treatment difficult if not impossible.

Special heat-treatment equipment

Frequently, pre-heat or post-heat treatment or both are required. For example, air-hardening steels such as the Cr-Mo creep-resisting types must be pre-heated to reduce cooling rate of weld and heat affected zone and thus prevent cracking. They also require post-heat treatment to relieve internal stresses, set up by welding and to give the required mechanical properties. Even mild steel is sometimes stress relieved after welding and forming.

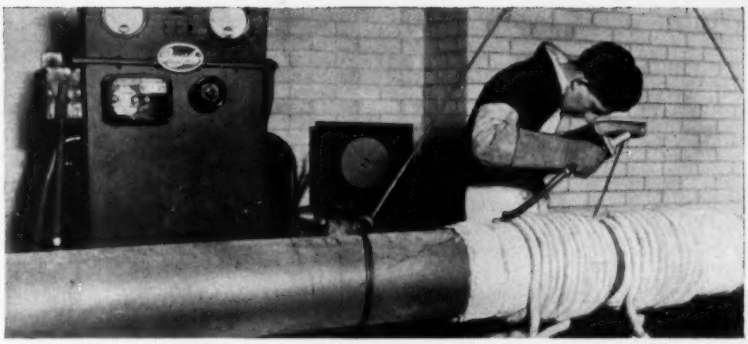


Fig. 4. Special heating equipment shown here provides the advantages of induction heating, but uses ordinary 50-cycle supply.

Work in the shop can be passed through a furnace, but on site, local stress relief of welded pipe joints can be carried out in three ways: (1) gas heating, (2) electrical resistance heating, or (3) induction heating. Induction heating is the most satisfactory as this method ensures a controlled heat cycle, without a sharp heat gradient through the pipe thickness. High frequency methods are usually unnecessary since 50-cycle equipment is adequate for most site requirements. Such equipment has the advantage of being relatively cheap and very robust. Two sizes made by Quasi-Arc are rated at 600 and 1,000 amp. continuously, and the smaller type is illustrated in Fig. 4. As an indication of operating speed a 600-amp. induction heater will raise a 16 in. o.d. by 1 in. thick pipe in the local area of the butt joint to 650°C. in approximately ½ hr.

The equipment is economical, easy to operate, and provides close control over the whole temperature cycle. The coils, as seen in the illustration, are simply wrapped round the joint before welding. They are asbestos-covered for protection.

Types of plant

The choice of welding plant depends on the availability of power, and the class of material to be welded. If no power is available obviously engine-driven equipment must be used. In this respect, the full economies of supplying local power are probably not fully appreciated. The accompanying table shows that the cost of engine-driven equipment is very high. It might, on a large project, for example, be worth bringing up a cable on site even if the cost was several hundred pounds, rather than be landed with the overheads unavoidable with engine-driven equipment.

Transformers ..	3d.	Based on 1d. per unit for electricity
Metal rectifiers	4d.	
Motor generators	7d.	
Diesel	31d.	
Petrol	71d.	

It is normal to provide d.c. for site welding, although an appreciable amount of arc welding, particularly of mild steel, can be carried out satisfactorily with a.c. Mains driven equipment giving direct current output is available in two types, *i.e.* rotary motor generators, or the modern selenium metal rectifier, which has the advantage of lower running costs, reduced maintenance and superior arc characteristics. One of the important advantages of a rectifier is that, unlike a motor-generator set, it only operates when welding is taking place. Further, it can more readily be protected against chemically laden atmosphere.

Most of the automatic welding techniques can be used over a wide range of application for such purposes as the fabrication of vessels. In general, the open arc systems are more tolerant to plate fit-up, moisture, rust, and so on than the submerged arc types. There is also the advantage that a wider range of covered electrodes is available, since the alloying elements introduced into the coverings are readily available, while equivalent alloyed bare wires for submerged arc welding are not always procurable in the United Kingdom.

The process is applicable to welding mild steel, creep-resistant steels, stainless, and a wide range of hard facing materials, in addition to copper-bearing steels for certain applications where resistance to corrosion is required. Welding speeds of submerged arc and *Fusarc*/CO_2 are comparable, although the submerged arc process, where applicable, can show speed advantages using the parallel welding or the multi-power system, which

offer speeds 50% and 100% faster than with normal submerged arc methods. In the first case two wires and one power source are used, in the second case two wires and two separate power sources are used.

How the plant engineer can help

Summarising, designers and planners of chemical processing plants can increase welding efficiency in a number of ways, and so can those responsible for preparation. The following points should always be borne in mind:

(1) Ensure that the joint design is correct for the particular weld. Only $\frac{1}{16}$ in. too much in preparation can result in a disproportionately larger consumption of expensive weld metal and an increase in distortion.

(2) If gas-cut edges are used they must be very good to be acceptable. For high-quality work the normal practice is to machine them.

(3) Joints should be in such a position as to be accessible for welding and heat treatment. For example, a pipe running down the side of a vessel will be almost impossible to weld satisfactorily because the welder cannot get proper access to the joint.

(4) Reduce site welding to a minimum. Make fullest use of prefabrication.

(5) To ensure correct choice of electrode, give the electrode manufacturer the fullest possible information as to code requirements and operating conditions. In some instances chemical and oil companies have their own specification, which the electrode manufacturer can usually meet, provided that full information is given.

(6) Select equipment on the soundest economic basis, even though it may involve greater initial expenditure.

The author thanks Quasi-Arc Ltd. for supplying information and photographs contained in this article.

£ s d

CHEMICAL PLANT COSTS

Cost indices for the month of September 1958 are as follows:

Plant Construction Index: 176.0
Equipment Cost Index: 164.0
(June 1949 = 100)

£ s d

Company News

We were privileged to attend, as special friends of the company, the Jubilee dinner of Kestner Evaporator and Engineering Co. Ltd., at the Savoy Hotel, London, on October 21. We recall with pleasure a similar dinner held six years ago on the occasion of the 80th birthday of the founder and chairman of the company, Mr. J. Arthur Reavell.

At 86, Mr. Reavell, as mentioned in a personal note in our August issue (page 298), is still in active control of the company he formed in 1908. Many men start enterprises, but few have the pleasure and satisfaction of living long enough to see them reach their golden jubilee.

*

A new plant for the polymerisation of a wide range of polyvinyl acetate emulsions is now on stream at Slough, Bucks. Owned by National Starch Products Inc., New York City, U.S.A., the plant is operated by National Adhesives Ltd., a subsidiary.

According to Mr. A. R. G. Williams, managing director of National Adhesives' British operations, the new plant will provide a centre for research and technical service facilities for emulsion technology in Britain. At the same time it will encourage the free exchange of new developments in these fields between National's British technologists and the company's research and development personnel in the United States. As such, the opening of the Slough plant marks a major expansion in National Adhesives' activities.

*

Pfizer Ltd. have announced the acquisition of Kemball, Bishop & Co. Ltd., whose products include tartaric, citric and gluconic acids and their salts, lithium salts, rubidium salts, itaconic acid, kojic acid and various others. In 1935 the company was granted a licence by Chas. Pfizer & Co. Inc., New York, for the manufacture of citric acid by fermentation processes and, at the same time, the American company became a shareholder.

The intention of Pfizer Ltd. is that Kemball, Bishop will continue as a separate entity handling the group's bulk fine chemicals.

*

The new company formed by Imperial Chemical Industries Ltd. and Celanese Corporation of America for the purpose of manufacturing in the United States a polyester fibre that is chemically the same as *Terylene* will initially be known as the Lindum Fibres Corporation.

The board of the new company has been constituted as follows: from Celanese Corporation of America—Mr. J. H. Black (president), Dr. R. T. Armstrong, Mr. J. W. Brooks and Mr. G. H. Richards; from I.C.I.—Mr. E. A. Bingen, Dr. A. Caress, Dr. E. D. Kamm and Mr. C. I. Rutherford.

*

A new factory for the manufacture of oxygen and dissolved acetylene has been opened by British Oxygen Gases Ltd. on the Raynesway Industrial Estate at Derby. The company now has 46 oxygen producing and compressing centres and 20 for dissolved acetylene in operation throughout the country.

The oxygen compressing station includes a cylinder filling and loading deck, and a feature of the factory is a pipeline for gas supply which connects the local locomotive and carriage works of British Railways.

*

Changes of address

The head office of Midland Silicones Ltd. has moved to 68 Knightsbridge, London, S.W.1.

Acheson Industries (Europe) Ltd. has moved to 1 Finsbury Square, London, E.C.2.

The Changing Pattern of Gas Manufacture

(*Concluded from page* 398)

case of carbonising plant, they possess the advantage over the latter in respect of greater flexibility of operation.

The new processes will also provide means of producing a considerable range of chemical substances, and can be controlled, if occasion should require, so as to make gas or chemicals as the main product.

A further point is the production of town gas containing practically no sulphur. This is becoming an important factor in the field of competition of gas with other fuels.

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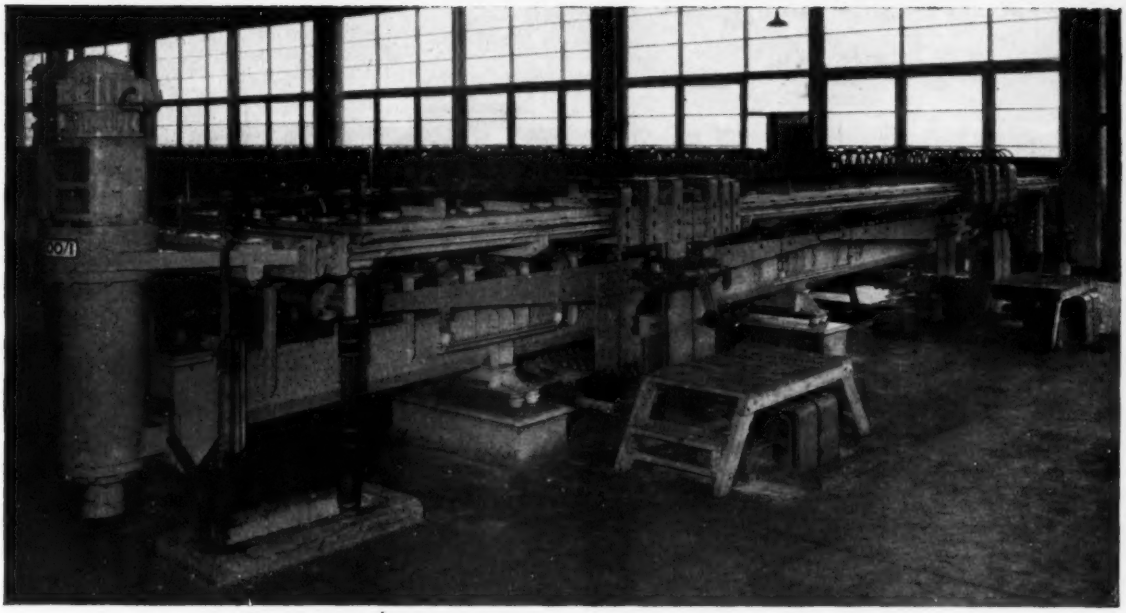
[12]R. H. Griffith and F. J. Dent, *Ibid*, G.C.8.
[13]R. S. Andrews, Inst. Gas Engrs. Comm. 503 : 1957.



View inside the mercury cellroom at the Ellesmere Port chlorine plant.

Chlorine for Tetraethyl Lead

ASSOCIATED ETHYL'S NEW BRINE ELECTROLYSIS PLANT

The new chlorine plant of Associated Ethyl Co. Ltd. at Ellesmere Port, Cheshire, which came into production earlier this year, represents a considerable addition to Britain's heavy chemical industry. Notable features of the plant include the high degree of instrumentation, the attention that is paid to orderliness and cleanliness, and the well-integrated safety arrangements. Another notable feature is the germanium rectifier unit, believed to be the largest industrial unit of this type to be found in Europe.

THE plant produces chlorine by the electrolysis of brine, chlorine being supplied in liquid form to the adjacent tetraethyl lead factory at Ellesmere Port where it is used in the manufacturing of ethyl chloride and ethylene dichloride. Some of the chlorine also goes to the company's plant at Hayle, Cornwall, and Amlwch, Cheshire, for the extraction of bromine from sea-water. The chlorine plant has a capacity to produce between 20,000 and 40,000 tons p.a.

The plant is situated on a 30-acre site close to the River Mersey and the Manchester Ship Canal, and extensive piling was necessary before construction could begin. Process design was done within the company and construction was carried out by contractors under the direction, co-ordination and supervision of company site management.

Salt supplies and brine preparation

Vacuum salt is delivered to the factory from two external sources in both road and rail vehicles. These vehicles discharge into three lined storage pits. This salt is used to re-concentrate weak brine after electrolysis.

Pure concentrated brine is fed to the cells. It leaves the cells at a lower concentration and is then slightly acid due to dissolved chlorine. The chlorine is removed from the brine by (*a*) acidification, (*b*) vacuum and (*c*) air blowing. Remaining traces of chlorine are removed by treatment with sodium sulphide solution.

A third part of the dechlorinated brine stream is fed into one of the salt storage pits and serves to carry a slurry of salt into the brine preparation tanks where this slurry is agitated with the remainder of the brine to resaturate the solution. NaOH, Na_2CO_3 and $BaCO_3$ are also added to remove magnesium, calcium and sulphate.

Since the principal brine impurity will be sulphate, the sludge from brine purification will consist chiefly of barium sulphate. The resulting precipitates are removed by filtration through two Kelly pressure filters in series, with provision of intermediate storage.

All brine equipment is constructed of materials that are anti-corrosive and will not give risks of contamination of the brine with traces of elements (V, Cr, Mo) which are known to cause decomposition of sodium amalgam. Much of the equipment is rubber-lined. The brine handling equipment is lagged to minimise heat losses and an approximate heat balance is achieved.

Most of the water leaving the cells with the chlorine gas will be condensed and returned to the brine circulation. The salt as received will contain about 2% moisture, and consequently the brine system is approximately self-balancing for water requirements.

Mercury cells

The chlorine production unit consists of mercury cells, based on the Badische Anilin-& Soda Fabrik design, each of 30,000 amp. capacity. The general features of B.A.S.F. mercury cells have been described in various publications.

The cells are installed on the first floor of a two-storey building, the associated pipework being suspended under this floor. Floors and drainage systems are so constructed that losses, due to possible spillage of mercury, are minimised by installing mercury traps.

Chlorine liquefaction

After cooling, the chlorine passes through three towers in series through which sulphuric acid is circulated. This renders the chlorine sufficiently dry to be subsequently handled in mild-steel equipment without serious corrosion.

Nash compressors, sealed with sulphuric acid, compress the chlorine and deliver it to two liquefiers in series. Liquid chlorine drains *via* sealing lutes to storage tanks of 50 tons capacity, and ' tail gas,' which contains some unliquefied chlorine and also the incondensible gases originally present in the chlorine, passes through a pressure control valve to an absorption system.

Analytical tests and recording katharameters are used to check the content of hydrogen in the inlet and ' tail gas ' of the liquefiers. Additions of air may be made to the chlorine gas stream in order to ensure that the explosive range is avoided by an adequate safety margin.

The storage tanks are mounted on semi-weighscales and are all connected *via* a pressure release vessel. This is designed to avoid any risks of hydraulic pressures on the storage tanks, which might possibly arise if they were, by faulty operation, completely filled with cold liquid chlorine and subsequently allowed to increase in temperature.

From the storage tanks the liquid chlorine is transferred to road or rail tankers by a pressure of dry air. Provision has also been made for future installation of liquid chlorine pumps.

All liquid chlorine vessels are constructed of *Coltuf* steel to eliminate embrittlement risks which might otherwise be present due to the low temperature of the liquid chlorine. PTFE has been used for liquid chlorine valve gland packings.

Weak chlorine absorption systems

To avoid any discharge of chlorine to atmosphere, towers circulated with diluted caustic liquor have been provided to absorb all chlorine which cannot be utilised. Arrangements have been made for treatment of all liquid effluent from this system before discharge. In normal operation the caustic absorption system will only be used for the small quantity of highly diluted chlorine present in the air from the air-blowing section of the brine dechlorination plant. The towers have, however, been designed such that the total chlorine produced at the cell-room can be absorbed for a short period. Chlorine ' tail ' gas and vent gases from transfers can also be absorbed here, but these gases will normally be fed to the chlorine recovery plant and the total chlorine content subsequently re-fed to the main liquefiers. The chlorine recovery plant includes an absorbing and stripping column and is designed to receive weak chlorine both from the mercury cell factory and also, by interconnecting pipeline, from the adjacent factory where Down's cell chlorine is liquefied. This recovery plant will not be in operation until later in the year.

Safety provisions

In addition to the more usual chemical hazards associated with corrosive liquors such as vitriol, caustic soda, hydrochloric acid and sodium sulphide solution, design and operating methods of the process have provided numerous safeguards for the handling of hydrogen, chlorine gas, liquid chlorine and mercury. Advice was received from I.C.I. Ltd., General Chemicals Division, on liquid chlorine storage and transport.

The problem of hygiene with mercury was not dissimilar to the existing experience in the company of control of possible hazards with lead. A comprehensive system of monitoring and control is in application.

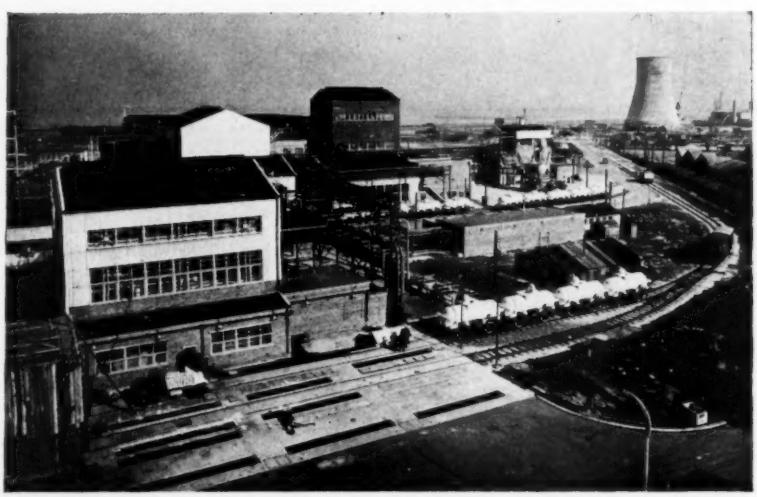
Emergency electrical power supplies (based on a diesel generator) will automatically restore the supply of a.c. current to important items of equipment such as mercury pumps, chlorine fans and certain brine pumps.

Considerable thought has also been given to communication systems to assist the safety and smooth operation of the plant. In addition to various alarm systems, telephone systems, and *Clearcall* inter-communications, provision has also been made for immediate interruption of the total electrolysing current to the cells from strategic points in the process.

Instrumentation

Full use has been made of latest available types of instruments. Special instruments include *p*H, *E*h, turbidity and density meters for brine, conductivity meters for decomposer feedwater, analysis instruments for chlorine strength, hydrogen and moisture content of chlorine, oxygen and mercury in hydrogen. The density of caustic liquor and the volumes of caustic liquor discharges from storage tanks is also recorded.

' Flow sheet ' instrument panels are



View of Ellesmere Port plant with underground salt storage pits in the foreground.

Another view inside the cellroom.

installed at both the cellroom and the liquefaction plant.

Contractors and suppliers

Mechanical, electrical and instrument engineering design was carried out partly within the company and partly by Matthew Hall & Co. Main contractors employed during the construction of the chlorine plant were George Wimpey & Sons Ltd. (building and civil engineering construction), D. & C. and William Press Ltd. (mechanical plant erection), W. H. Smith & Co. Ltd. (electric plant), British Thomson-Houston Co. Ltd. (rectifier plant and associated switchgear), J. & E. Hall Ltd. (chlorine refrigeration plant), and Constructors John Brown Ltd. (instrument installation).

Subsidiary contractors and suppliers included H. Balfour & Co. Ltd. (mild-steel fabricated vessels), Thomas Bolton & Sons Ltd. (copper busbars), British Acheson Electrodes Ltd. (graphite components for electrolytic cells), Brown Fintube (Great Britain) Ltd. (heat exchangers), Crompton Parkinson Ltd. (motor generating equipment), Davenport Engineering Co. Ltd. (cooling water towers), Davey, Paxman & Co. Ltd. (mild-steel fabricated tanks and towers), Doulton Industrial Porcelains Ltd. (porcelain insulators), English Electric Co. Ltd. (fused switchgear and distribution boards), Fisher Governor Co. Ltd. (instruments), F. Haworth Ltd. (chemical brick lining), Honeywell Controls Ltd. (instruments), Kestner Evaporator & Engineering Co. Ltd. (process pumps), L. A. Mitchell Ltd. (stoneware process pumps), Murex Arc Welding (welding equipment), Powell-Duffryn Carbon Products Ltd. (graphite components), Sigmund Pumps Ltd. (process pumps), Silvertown Rubber Co. Ltd. (rubber lining), Heppenstall & Sons Ltd. (mild-steel tanks) and many others.

Contracts

Fertilizers & Chemicals Ltd., Israel, have concluded a contract for the sale of ' know-how ' for the production of dicalcium phosphate to Krebs & Co., of Paris, who are erecting a DCP plant in accordance with this process in Belgium.

Some of the equipment will be manufactured by F. & C. and supplied to Belgium.

*

The Power-Gas Corporation Ltd. has recently put into operation a Power-Gas/Hercules hydrogen plant, at Warrington, for Laporte Chemicals Ltd. The reforming plant is producing high-purity hydrogen. It consists of the reforming furnace followed by three stages of CO conversion and CO_2 removal with final methanation. The additional stage of conversion is to reduce the final residual methane to a minimum. A Wiggins dry-seal gasholder has also been erected on this site.

*

Two mechanical gas producers are to be built by Humphreys & Glasgow Ltd. to supply gas for firing lime kilns at Carbide Industries' new works near Londonderry, which will produce calcium carbide and also acetylene. The acetylene will be supplied to du Pont (U.K.) Ltd. for making *Neoprene*, a specialised synthetic rubber.

Gas firing of the kilns has been chosen to provide a use for by-product gases from other parts of the works. These gases will be supplemented with gas from the new producers, which will be of 7-ft. diam.

*

Two medium- and one high-capacity hydrostatic fruit steriliser are being shipped to Australia as part of a contract, worth £35,000, awarded to the food machinery division of Mitchell Engineering Ltd.

These machines are fully automatic and form part of a programme being completed to mechanise the high-speed processing lines of two Australian canning companies: Ardmona Fruit Products Ltd. and Riverland Fruit Products Co-operative Ltd.

*

Whessoe are to be awarded the contract for the supply and construction of the reactor pressure vessel for the advanced type of gas-cooled, graphite-moderated nuclear reactor to be set up by the U.K.A.E.A. This plant will operate at considerably higher temperatures than those employed on nuclear power stations currently under construction.

The 'A.G.R.' pressure vessel containing the core and moderator is a vertical cylinder of approximately 21 ft. diameter with hemispherical top and bottom heads. Its overall height is 53 ft. 6 in. and it is to be constructed from notch ductile steel plate of considerable thickness. The top head is perforated by a large number of closely pitched charge tube and control rod standpipes for refuelling and controlling the reactor.

The internals are most complex. They include the support of the heavy core and graphite moderator and the shielding material. The internal baffles are arranged in such a manner that the relatively cool inlet gas sweeps the entire pressure vessel shell. The hot gas is collected from the reactor channels and passes out of the reactor through an inner concentric duct. This prevents it being in contact at any point with the vessel shell.

This nuclear reactor vessel will be the twelfth to be built by Whessoe, whose first contract for a reactor pressure vessel was secured in 1953.

Recent British Patents

Phenol recovery

A process and plant, the latter shown in a diagram, have been devised for the recovery of phenol from coke plant ammonia liquor. Existing processes remove about 90% of the phenol. The remaining 10% forms, in the aggregate, a large quantity, which is not only valuable, but which contaminates the water of rivers or lakes into which the waste liquor is discharged. The process consists of extracting the phenol with a liquid solvent for phenol, but of lower density than water and immiscible with it, such as benzene. The separated phenol solution is extracted with aqueous caustic soda. Both extractions are carried out in centrifugal countercurrent extractors. The sodium phenolate is treated conventionally to recover the phenol. The benzene or other solvent is recirculated. The recovery of phenol from the liquor is claimed to be 94% or higher.—799,327, *Allied Chemicals & Dye Corp.* (*U.S.A.*).

Sulphonation of organic compounds

In sulphonating or sulphating organic compounds by reaction with chlorosulphonic acid or gaseous sulphur trioxide, carried in a stream of air or other inert gas, many difficulties are encountered, the chief of which is in the control of temperature. While the reactions are exothermal, causing too high a temperature, it is necessary, in many cases, to heat the starting material to a rather high temperature to liquefy them and commence the reaction. The present invention relates to a continuous process in which sulphonated products are cycled, with periodical or continuous withdrawal of portions, fresh raw materials being supplied to the circuit at the same rate.

In the first of four examples, which refer to an appended drawing, the sulphonated product in circulation amounts to about 2,000 kg. There are introduced hourly 200 kg. of mixed primary fatty alcohols having 8 to 18 carbon atoms and a mean molecular weight of 200, and a mixture of 800 cu.m. of air with 80 kg. of sulphur trioxide. Removal is at the rate of 280 kg./hr. Throughout the reaction the temperature is easily kept at 23°C., the melting point of the fatty alcohols being 20.5°C. — 799,199, *Societe Anonyme d'Innovations Chimiques dite 'Sinnova' ou 'Sadic'* (France).

Cracking of hydrocarbons

In cracking hydrocarbons for the production of olefines by a fluidised solid process there is inevitably a small loss of entrained solid carried away in the current of gas or vapour. At 630 to 850°C., side reactions occur in the space between the surface of the fluidised layer and the separation apparatus for the entrained solids. It has been found possible to avoid these reactions by enriching the gaseous reaction mixture, immediately above the fluidised layer, at about the temperature of the latter, with pulverised or granular inert or carbonaceous material, so that the solid content of the space referred to is advantageously 1 to 20 kg., preferably 2 to 20 kg./cu.m. The coarsest possible grain size of the added solids is chosen. The preferred carbonaceous solids are high-temperature coke or oil coke produced by cracking, for use in the cracking of hydrocarbons of high boiling points. Suitable inert materials are sand, pumice and alumina.

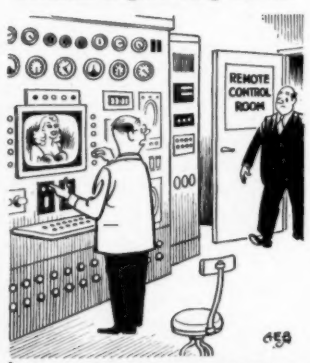
A shaft furnace, illustrated by a drawing, is described, with an application of the process, in an example. —799,289, *Badische Anilin-& Soda-Fabrik* (Germany).

Regenerating polyamides

Polyamides of low molecular weight, such as nylon scrap, having a moisture content of more than 0.05%, have their properties improved by melt extrusion under reduced pressure, such as 200 mm. of mercury, at a temperature below 325°C., which is equal to or above the melting point, but below the decomposition temperature. By this treatment the moisture content falls below 0.5%, and the inherent (intrinsic) viscosity of the product is increased by at least 0.1 to a value of 1.0 or more.

The extrusion apparatus, shown in a drawing, is provided with a reduced pressure section. The raw material may be in almost any form of small pieces. The charging hopper should be operable in the presence of nitrogen, carbon dioxide or other inert gas. In the section of reduced pressure, the latter and the residence time are adjusted to reduce the free moisture and to increase the viscosity of the melt, which is extruded to give desirably shaped products, such as pellets, rods, tubes, etc.—799,328, *E. I. du Pont de Nemours & Co.* (U.S.A.).

Comical Engineering Corner



"SOMETHING SEEMS TO HAVE GONE WRONG WITH THE TV SCREEN, SIR — I KEEP GETTING SABRINA"

Flexible pump diaphragm

Apart from the lack of resilience needed to ensure ease of flexing when used as a diaphragm material in pumps, *Teflon* (polytetrafluorethylene) is an ideal substance for such purposes. It is inert chemically from extremely low temperatures to about 570°F., and to some of the most corrosive chemicals at their boiling points. It is also insoluble in all solvents.

Diaphragms of *Teflon* or other materials which are not very resilient are so constructed as to have relatively movable central and peripheral regions, the intermediate regions being more flexible. Flexibility is achieved by the use of multiple layers of material, the layers being capable of independent movement. This assembly is joined to the central and peripheral regions. The advantages of the flexibility of the thin layers and the strength of the total thickness are thus secured. The method of manufacture of the diaphragms is described and illustrated by drawings. — 799,335, *Crane Packing Co.* (U.S.A.).

Retort for zinc white

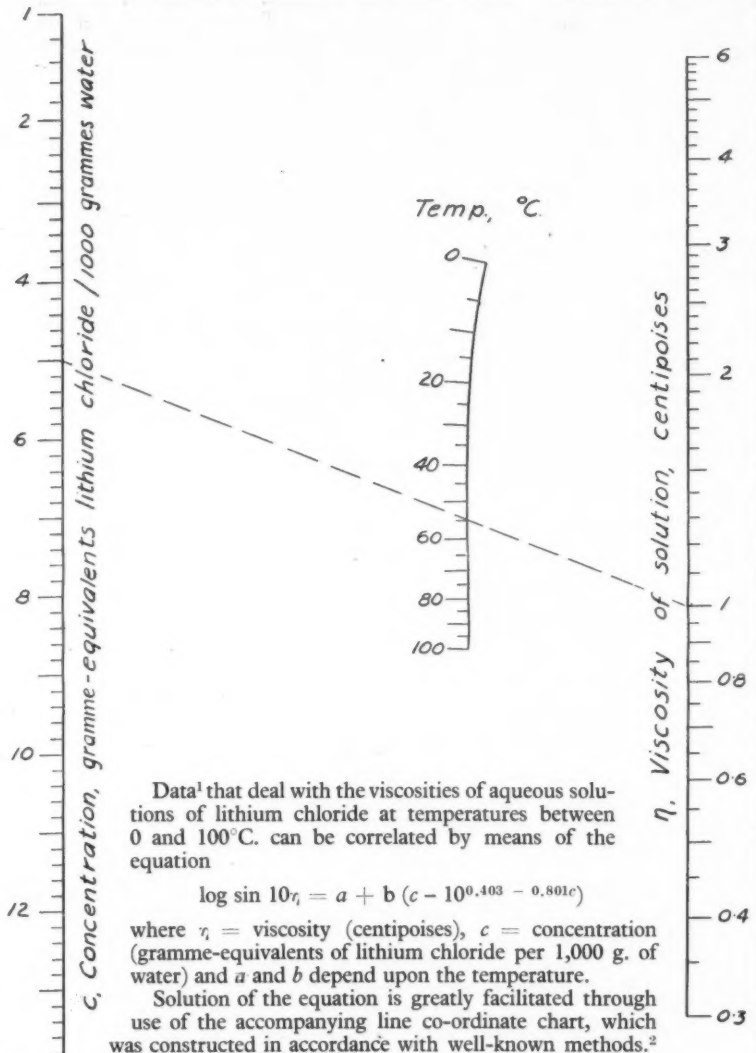
A retort has been designed for the manufacture of zinc white. It is constructed of fireproof material such as graphite and is open only at one face. Except for the charging opening provided, the retort lies wholly in the fire space. To introduce a scavenging gas, a conduit, extending inwards to the middle part of the retort, forms an integral part of the wall or is affixed thereto. The gas flows out with the zinc vapours through the charging opening, which may be closed by a cover having a gas passage therein.—800,104, *Guenther Dudek* (Germany).

Nomogram:

Viscosities of Aqueous Solutions of Lithium Chloride

By D. S. Davis

(*Head, Department of Pulp and Paper Technology, University of Alabama*)



Data[1] that deal with the viscosities of aqueous solutions of lithium chloride at temperatures between 0 and 100°C. can be correlated by means of the equation

$$\log \sin 10\eta_i = a + b\,(c - 10^{0.403\,-\,0.801c})$$

where η_i = viscosity (centipoises), c = concentration (gramme-equivalents of lithium chloride per 1,000 g. of water) and a and b depend upon the temperature.

Solution of the equation is greatly facilitated through use of the accompanying line co-ordinate chart, which was constructed in accordance with well-known methods.[2] Application of the chart is illustrated as follows: At 55°C., what is the viscosity of an aqueous solution where lithium chloride, the only solute, is present to the extent of 5 gramme-equivalents per 1,000 g. of water? Connect 5 on the c-scale and 55 on the temperature scale with a straight line. Extend the line to meet the viscosity scale at 1.00 centipoise.

REFERENCES

[1] 'Product Data,' No. 26. Lithium Corporation of America, Minneapolis, Minnesota.

[2] D. S. Davis, 'Nomography and Empirical Equations,' Chap. 10. Reinhold Publishing Corp., New York, 1955.

Personal Paragraphs

★ **Mr. C. I. Rutherford** has been appointed a director of the Fibres Division of Imperial Chemical Industries Ltd. He joined the central instrument section of I.C.I.'s head office in London 12 years ago and, two years later, he was transferred to the technical department in head office. In 1951 he first became associated with *Terylene* when he joined the technical department of the *Terylene* council. He was appointed manager of the *Terylene* pilot plant at Hillhouse in 1953, a post which he held for three years. Mr. Rutherford came to the Fibres Division headquarters in 1956 as assistant research manager and, in 1957, was appointed production manager, a post which he held until his latest appointment.

★ **Mr. G. H. Thackrah** has been appointed sales manager to Markland Scowcroft Ltd., mild-steel fabricators and suppliers of mechanical tubing and storage tanks.

★ **Mr. P. V. Colebrook,** production and research director of Pfizer Ltd., has been appointed managing director of the company. He joined Pfizer in 1952 as works and production manager and became one of the company's youngest directors anywhere in the world when two years ago, at the age of 32, he was elected to the Pfizer Ltd. board. After leading the rapid building up of the production teams and facilities he was given overall responsibility for quality control and research. He instituted the firm's educational programme providing for university and 'sandwich' training courses.

★ **Dr. H. Moore,** C.B.E., has been elected an Honorary Member of the Iron and Steel Institute, of which he has been a member for 57 years. Of the other twelve living Honorary Members only one, Sir William Larke, is British. Dr. Moore was president of the Institute of Metals from 1934 to 1936, he was the first president of the Institution of Metallurgists, he was treasurer-editor of the Society of Instrument Technology from 1949 to 1956, is a founder Fellow of the Institute of Physics, and has served on the councils of the Royal Institute of Chemistry and the Faraday Society.

★ **Mr. R. W. Fox** recently celebrated his 40th anniversary with Mobil Oil Co. During the past few years, he has been the company's co-ordinator for lube and allied products in the technical services department.

World News

FRANCE

European chemicals still expanding

After its slightly slower rate of expansion in 1956, chemical production in O.E.E.C. countries increased by 10% in 1957, whereas total industrial production increased by 5%, according to the latest report prepared by the Chemical Products Committee of the O.E.E.C. in Paris. For the whole of 1958, chemical production will again increase, but most probably more slowly than in 1957. For instance, chemical production in the first six months of 1958 was 6% greater than in the first six months of 1957, the corresponding figure for total industrial production being 3%. As in recent years, the sectors expanding most rapidly are petroleum chemicals, plastics and nitrogenous fertilisers.

Investment in the chemical industry in 1957 is estimated to have been $1,000 million, which is some 7% above the 1956 figure.

AUSTRALIA

Epoxy resins project

Australia's first plant for the manufacture of epoxy resins, which will be marketed under the *Epikote* trademark, is to be built at Clyde, Sydney. This will be Shell's first chemical plant in New South Wales and their second in Australia. The other is the new sulphuric acid plant at Geelong, Victoria, just beginning production.

The *Epikote* resin plant is expected to be completed early in 1960 and will cost over £A600,000. It will manufacture both liquid and solid grades of *Epikote* and is designed to meet Australia's present requirements, with allowance for future expansion as the expected demand increases.

PORTUGAL

Ammonium sulphate

New installations recently inaugurated at the works of Amoniaco Portugues S.A.R.L. at Estarreja will raise the minimum annual production of ammonium sulphate by this factory to 70,000 tons. The new installations have cost 240 million escudos, and were supplied from Western Germany; they were included in the 1953-58 six-year development plan.

The programme still under way is to cost more than 1,500 million escudos and to attain an annual production of 350,000 tons of nitrogenous fertilisers.

CUBA

Fertiliser plant

A new firm, the Cuban Nitrogen Co., is erecting a nitrogen plant in Matanzas, which is due to start production in January-February 1959.

AUSTRIA

Polypropylene plant

The agreement for the establishment of a petrochemical plant, the Danubia Petrochemie A.G., has been concluded between the Oesterreichische Stickstoffwerke A.G. Linz and the Italian Montecatini Co. The first stage of construction, which will cost between 120 and 150 million Schillinge, is to have a productive capacity of 5,000 tons p.a. of polypropylene.

NORWAY

Aluminium

The new aluminium works at Mosjöen is reported to be now in full production. Annual capacity is something over 20,000 tons. Höyanger aluminium works has started using 44 new electrolysis ovens, which will increase capacity from 9,000 to 13,500 tons p.a.

DOMINICAN REPUBLIC

Fertiliser industry's success

Fertilizantes Quimicos C. por A., the company whose £250,000 plant in San Pedro de Macoris was equipped under the policy of government aid to new industries, now has an annual production figure of 240,000 tons. Prices are reported to be competitive with imported fertilisers.

WESTERN GERMANY

Formaldehyde manufacture

Reichhold Chemie A.G. in Hamburg have recently completed their own formaldehyde plant and have gone on stream. The annual production will be some 5,000 tons. Although formaldehyde is produced in the U.S.A. by Reichhold Chemicals Inc., it has not previously been manufactured in Europe by one of R.C.I.'s affiliates. Thus R.C.I. has taken another step in its long-range programme aimed at establishing itself as a leading producer of basic industrial chemicals in Europe, as well as Western Germany.

MEETINGS

Institution of Chemical Engineers

November 11. 'Design and Operation of Refrigeration Plant in the Chemical Industry,' by D. M. Elliott and R. Parkins, 6.30 p.m., Manchester College of Science and Technology, Jackson Street, Manchester.

November 19. 'Chemical Engineering Aspects of Tar Acid Recovery,' by D. McNeil, 6.30 p.m., Birmingham College of Technology, Gosta Green, Birmingham.

November 25. 'An Extended Equation for the Performance of Machines Mixing Two Powders,' by H. E. Rose, 5.30 p.m., Geological Society, Burlington House, London, W.1.

November 25. 'Pollution Law and the Chemical Engineer,' by R. R. Ferner, 7 p.m., Birkenhead Technical College.

December 2. 'Wetted Area in Packed Towers,' by W. S. Norman and B. Solomon, 6.30 p.m., Manchester College of Science and Technology.

Society of Chemical Industry

Chemical Engineering Group

November 11. 'The Integrated Iron and Steel Works,' by W. B. Wright and W. Elland, 6 p.m., 14 Belgrave Square, London, S.W.1.

December 4. 'Titanium and Its Alloys as Materials of Construction for Chemical Plant,' by Dr. K. W. J. Bowen, 6 p.m., Chemical Department, University of Bristol, Woodland Road, Bristol.

Institute of Petroleum

December 3. 'Flow Properties of Distillates at Low Temperatures,' by J. F. Hutton, 5.30 p.m., 61 New Cavendish Street, London, W.1.

Society of Instrument Technology

November 13. 'Temperature Measurement,' by R. Postle, 7 p.m., Leapark Hotel, Grangemouth.

November 19. 'Flow Measurement with Particular Reference to the Dall Tube,' by D. H. Kent, 7 p.m., King's College, Stephenson Buildings, Newcastle-on-Tyne.

November 26. 'Instrumentation in Chemical Analytical Control,' by B. W. Bradford, 7 p.m., Grosvenor Museum, Grosvenor Street, Chester.

November 28. 'Analytical Instrumentation of Chemical Processes,' by J. D. Tallantire, 7.15 p.m., Scottish Building Centre, 425 Sauchiehall Street, Glasgow.

Incorporated Plant Engineers

November 11. 'Radioisotopes in Industry,' by W. G. Busbridge, 7.15 p.m., Engineers' Club, Albert Square, Manchester.

November 19. 'Cathodic Protection,' by L. B. Hogben, 7 p.m., Railway Hotel, Dartford, Kent.

November 25. 'Corrosion,' by D. W. Marshall, 7.30 p.m., South Wales Engineers' Institute, Park Place, Cardiff.

November 28. 'Statutory Regulations of Steam and Pressure Vessels,' 7.30 p.m., Imperial Hotel, Temple Street, Birmingham.

WHAT'S NEWS about

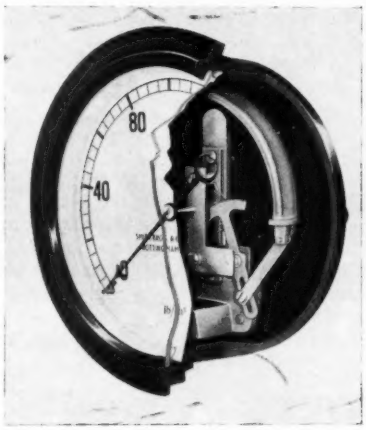
★ Plant
★ Equipment
★ Materials
★ Processes

This illustrated report on recent developments is associated with a reader service that is operated free of charge by our Enquiry Bureau. Each item appearing in these pages has a reference number appended to it; to obtain more information, fill in the top postcard attached, giving the appropriate reference number(s), and post the card (no stamp required in the United Kingdom).

Plastic-cased pressure gauge

A pressure gauge designed to stand up to particularly arduous conditions, offered by Smith Brothers & Co. (Hyson) Ltd., marks a departure from the standard brass- or iron-cased instruments. The block is of heavy construction and made from brass, steel or special metals, on which all the working parts are assembled. Bourdon tubes are shaped so that their reaction is regular to any application of pressure or vacuum. Through the connecting link this reaction is transmitted to the heart of the instrument —the movement, which being finely balanced and having broad teeth of cycloidal form on both quadrant and pinion, gives a smooth and positive action to the finely tapered pointer.

The contact parts of the gauge are of phosphor bronze, beryllium copper, steel, alloy steel, stainless steel or *Monel* metal so that instruments are available for use with both high- and low-pressure fluids of corrosive or non-corrosive qualities. Gauges of this type can be fitted with electric contacts for use in conjunction with automatic controls. **CPE 1049**



Cut-away view of pressure gauge.

Versatile manometer

Capable of being simply and quickly arranged for flush panel, wall mounting or, with special stand, for laboratory bench work, a new manometer is available for the measurement of pressure, differential pressures and levels at system pressures up to 100 p.s.i.g.

Special features of the equipment include the provision of two line-isolating valves and one equalising valve, and a simple, foolproof system for filling and venting the measuring fluid used.

Three standard instruments are available from Refinery Equipment & Speciality Co. Ltd. with scales of 6 in., 12 in. and 24 in. respectively; alternative scales are 15 cm., 30 cm. and 60 cm. and 0 to 100 square root. A free travel of 1 in. on each scale permits easy zero adjustment. **CPE 1050**

Tube cleaning

The removal of spent catalyst material from reactors and converters of the tubular type, using exhaust air to carry the recovered material up the tube and away past a deflector and dust seal to a container, is one of the specialised applications cited for *Lagonda* tube-cleaning equipment. Other uses include the cleaning of air preheaters which become completely plugged with fly ash.

A variety of cutter heads and brushes is available, to deal with straight or curved tubes from ½ to 6 in. or more internal diameter, all heads being variations of straight and trackless cone cutters in which the spacing of the cutter teeth or blades is so arranged that any one tooth does not return to the same point in a tube in successive revolutions of the head. This prevents the formation of a tooth design in the tube and ensures an even finish. Cutters and other head parts are heat treated. For straight tubes, the cutter heads are direct coupled to the shaft of the motor used, whilst to obtain flexibility in curved tubes, a universal joint is always used between the cleaner motor and the cutter. **CPE 1051**

Pipe flow calculations

Two new calculators of the circular slide-rule type for determining the flow of liquids and gases through pipelines have been announced by Fearns, Mear & Co.

These calculators, it is claimed, quickly and accurately give the rate of flow, pressure drop or required pipe size for all fluids, one instrument dealing with turbulent flow conditions and the other with the streamline flow of viscous liquids. They take into account the viscosity and specific gravity of the fluid and automatically allow for the established variation in the coefficient of friction according to the velocity and pipe size, so that their use is extremely simple.

The turbulent flow calculator deals with the majority of practical cases and has, on the reverse side, viscosity figures at various temperatures for a wide range of liquids, together with scales to confirm whether the flow is turbulent or streamline and also viscosity conversion scales.

Suitable for pipes from 0.1 to 40 in. in diameter passing from 0.1 to 1

million gal./hr., they are made in transparent and white *Perspex* with two colour-engraved scales, and supplied complete in cloth-covered cases.

A similar instrument will shortly be available for dealing specifically with the flow of water and covering large ducts, brick sewers, open channels, etc., in addition to pipes of various materials. **CPE 1052**

Electronic tank gauge

The *Gilbarco* electronic tank contents gauge is to be manufactured in Britain. It is claimed that greater accuracy than $\pm\frac{1}{16}$ in. has been recorded and that the gauge can be installed in tanks of all types at temperatures up to 425°F. and in quarry or underground storage to depths of 1,000 ft.

According to Firth Cleveland Instruments Ltd., the gauge reads the true level of the liquid regardless of its specific gravity, and is power-actuated to overcome the effect of varying friction and weight. It can be adapted to almost any type of remote transmission, can be equipped for automatic selection of temperature averaging resistance thermometers, and fitted with high- and low-level alarms. **CPE 1053**

'Keelavite' power pack.

High-resistance glass tanks

Tanks of polished plate-glass which has been subjected to heat treatment, giving it greatly increased mechanical strength and a high degree of resistance to mechanical impact and thermal shock, are offered by Q.V.F. Ltd. They can be used in trades varying from electro-plating to the soft drinks industry. It is stated that the only chemicals likely to affect the glass are hydrofluoric and glacial phosphoric acids, and strong caustic solutions. The continuous gaskets which seal the narrow joints are of a material selected to withstand specific chemical conditions. **CPE 1054**

Plastics tube monitor

An instrument to measure and monitor electronically the wall thickness and concentricity of plastics tube, as it is extruded, is announced by Haynes & Haynes Ltd. It consists of a detector head, through which the tube passes, and a control cabinet, which receives the information supplied by the detector head. On the control cabinet is a meter which shows the thickness of the tube being monitored.

The concentricity of the tube bore is checked by scanning the circumference of the tube with the head. A production record may be charted on the paper reel of an ordinary recorder. **CPE 1055**

New industrial coupling

An electro-magnetic form of coupling for industrial drives has the resilience of its fluid flywheel counterpart with the stability of a solid device. It is a constant torque unit, the torque being independent of speed, and has a safety feature permitting a certain amount of slip when necessary. There are no moving engaging components.

These couplings are available with torque capacity of $\frac{1}{3}$, 1, 6, 12, 25, 50, 100 or 200 lb./ft., and operate from 24 volts or 180 volts d.c. as standard, though special voltages can be catered for. Makers: S. Smith & Sons (England) Ltd. **CPE 1056**

Highly dispersed oxides

In addition to the highly dispersed oxide of silica, *Aerosil*, Degussa of Frankfurt (Main) are now regularly producing highly dispersed oxides of titanium, aluminium and iron which are made by the pyrogenic phase. Samples and data are available in the U.K. from Bush, Beach & Cent Ltd., or by filling in the reply-paid card. **CPE 1057**

Pre-packed hydraulic power

A useful range of hydraulic power-packs is announced by Keelavite Rotary Pumps & Motors Ltd. There are four sizes with tank capacities of $7\frac{1}{2}$, 20, 50 and 75 gal. and electric motors of up to 2, 5, $12\frac{1}{2}$ and 25 h.p., pump capacities being available to suit individual requirements.

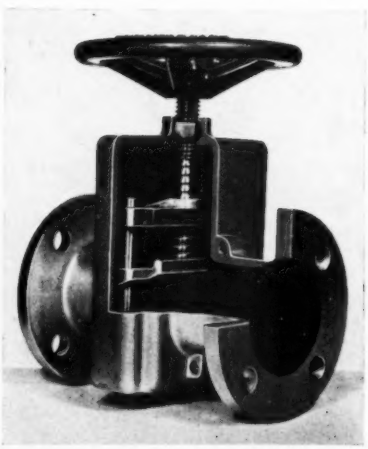
All packs are complete with suction-type oil filter (0.005 in. spacing), air breather and filler cap, drain tap, oil level gauge, pressure gauge with damping needle tap, and a suitable relief valve. For power-packs used in copying, profiling and other sensitive systems a pressure filter of 0.0008 in. spacing can be incorporated.

All packs are so designed that the valves most suitable for the job under consideration can be fitted. Many types of these units are available, such as relief valves, flow control valves, pressure reducing valves, and sequence and directional-control valves for local or remote-control operation. All valve gear is mounted on a detachable lid panel which, when removed, allows access to the pump and filter. **CPE 1058**

Pinch valve

In a new pinch valve, available in sizes from 1 to 3 in. bore diameter, die-cast construction has been used both for the casing and internal parts. At the same time, specially designed reinforced sleeves are used exclusively, all of which are suitable for internal pressures up to 100 p.s.i. The aluminium alloy casing is split on its vertical axis for ease of assembly and servicing, and completely encloses the flexible sleeve and operating mechanism.

The closing mechanism consists of



A 2-in. Rowe pinch valve.

two die-cast aluminium alloy anvils, a screwed spindle, and a handwheel, which operate to compress the sleeve equally from both sides. In turning the handwheel clockwise to close the valve it drops in a logical manner towards the top of the casing by a distance equal to one-half of the valve bore, and in doing so provides a ready external indication of the position of the valve. At the same time, the coarse-threaded section of the spindle causes the bridge and lower anvil to rise a similar amount to pinch the sleeve equally about its centreline.

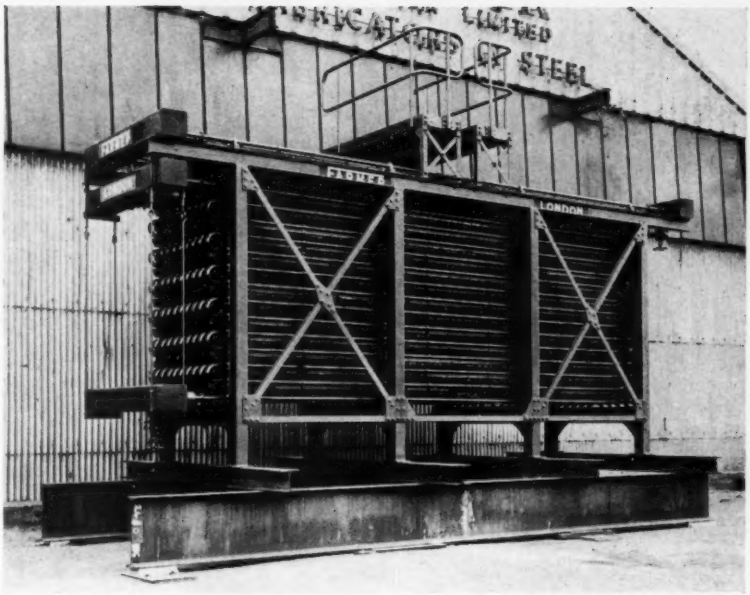
The reinforced sleeves are available in four grades of natural or synthetic rubber materials. W. H. Rowe & Son are the makers. **CPE 1059**

New wall-surfacing technique

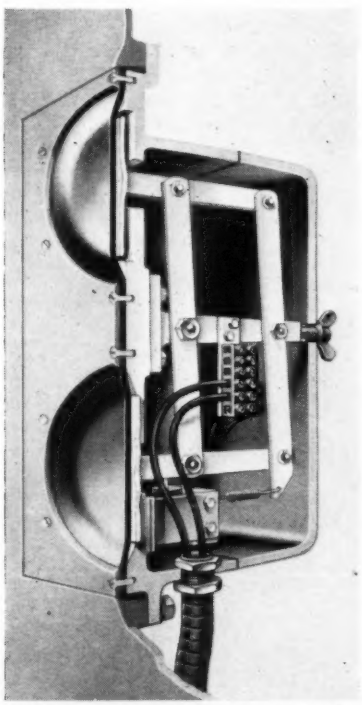
A new wall-surfacing technique is described as being equivalent to continuous tiling and applicable in almost any circumstances, to any base, without a join anywhere, no matter how large the area. It is pointed out that the system is superior to actual tiles for heavy-duty applications as there is no mortar or other jointing material.

The material is claimed to be completely stable under a wide range of temperature conditions from freezing point to about 140°F., and to withstand frequent fluctuations in temperature within that range. The treatment is also sufficiently flexible not to be disturbed by settlement in a new building.

The outer skin has a high water and chemical resistance, and can be applied to finish in white and colours, both light and deep toned. The treatment can be applied, without screeding or hacking, to a wide range of surfaces. It is relatively light in weight and can be made to follow any contour. Coltrate Ltd. are the makers. **CPE 1060**



These cooler coils, fabricated by S. W. Farmer & Son Ltd. and 'Sakaphen'-lined by Wolseley Holdings, give one example of the applications for these coatings.



Section through Blaw Knox double-diaphragm level indicator. Lower diaphragm is shown deflected, i.e. its position when covered by the material. When the material level falls the diaphragm resumes its original position and the spring-loaded 'even' beam operates micro switches to re-start material feed to silo or actuate warning devices.

Double-diaphragm level indicator

A new level indicator for the control of liquids, powders, granular and flaked materials has been designed by Blaw Knox Ltd. so as to be unaffected by build-up of air pressure or dense dust within a silo. It is suitable for high- or low-level control. The indicator is claimed to provide reliable control where pneumatic conveying systems are used. **CPE 1061**

Protective coatings for woods, concrete, cork and metals

For a range of protective coatings designed to combat corrosion, erosion and build-up troubles use is made of new synthetic resins to cover the entire *p*H range in liquid handling, up to maximum working temperatures of about 200°C. One grade of material is stable up to 450°C.

The coatings offered by Wolseley Holdings Ltd. and their associates in Germany, Saureschutz Rheinruhr, fall into three main types:

(1) Thermal-hardening coatings for application to plant at the Lancaster factory.

(2) Cold-hardening coatings both for application to plant at the Lancaster factory and to plant on site.

(3) Industrial paints.

The makers report that considerable success has been achieved both in the United Kingdom and on the Continent in coating plant of all types and sizes against the action of acids, alkalis, solvents, sea-water, vapours and gases, etc. The unique slip and release properties of the coatings have found extensive application in preventing bridging and accelerating the sliding of powders, dusts and coal in chutes and hoppers, etc. It is claimed that the non-toxic and insoluble nature of the materials make them particularly suitable for the lining of storage vessels for beverages including beer, fruit juices and wines, and of plant connected with food preparation, and that the requirements for the storage of fully demineralised water are adequately met. *Lanshield Sakaphen*

materials have found extensive application in the field of water treatment and heat exchange. Power stations, gas works, oil refineries, chemical manufacturers and atomic energy are among the fields of application cited.

The thermal-hardening grades are usually applied up to a maximum thickness of 0.010, giving a smooth, elastic finish, whilst the cold-hardening materials are applied up to about 0.030 in. thickness, although this can be increased by suitably reinforcing the resin layer.

The industrial paints based on the same materials provide protection to plant parts, buildings and structures liable to weathering by the atmosphere or corrosive vapours. **CPE 1062**

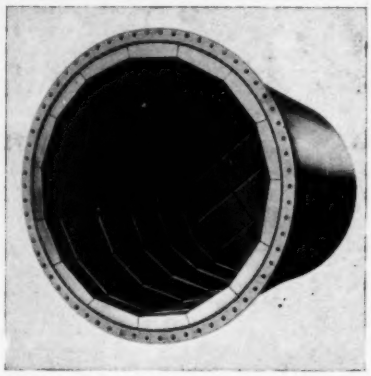
Protective coating

A coating which is aimed at giving exceptional thickness combined with good resistance to chemicals, oils, fats and general corrosive conditions is an epoxy/pitch combination with which a thickness of 0.010 in. can be built up with as little as two coats. It can be brush or spray applied to metal or concrete. By nature the paint is dark brown in colour, but certain decorative paints can be applied over it without bleeding.

The paint, made by Detel Products Ltd., is suggested for use on permanent structures such as cranes, bridges, as a lining for tanks and tankers and for mechanical handling equipment which may be dealing with abrasive dusts. **CPE 1063**

New lining for heating vessels

Aimed at overcoming the problem of heating corrosive liquids, a new type of lining has now been developed which acts as a heat exchanger and steam jacket at the same time. It consists of flat, impregnated, graphite tiles which are used to line cylindrical or similar vessels. The space formed between the curved steel shell and the flat back of the tile forms a channel



Vessel lined with graphite tiles.

through which steam or heat-exchanging fluids can flow. By cutting the supporting edges at certain places continuous channels are formed in any way which is suitable for the particular job.

Heat-transfer figures in the neighbourhood of 500 calories/°C./sq.m./hr. are claimed by the suppliers, Cahn & Bendit Ltd. **CPE 1064**

Steam generators

Oil-fired, compact, forced-circulation, water-tube boilers, providing an automatically modulating output in single or multiple installations, are made by J. Stone & Co. (Deptford) Ltd. Fully self-contained and easy to install, each of the range of models available is about one-quarter the size and one-fifth the weight of conventional boilers of the same rating. There is no waste of fuel or water since, owing to their quick-steaming characteristic, *Stone-Vapor* steam generators produce steam only when it is required. Other features include: installation without break in production, steam in 2 min. from a cold start, smoke-free combustion, the ability to cope with widely fluctuating loads in winter and summer, simple operation and maintenance, and efficiency at all rates of evaporation. **CPE 1065**

Low-temperature evaporator

The basic principle of the *Lo-Temp* is the heat pump in which ammonia extracts the heat from the product vapour; further heat is then added to the ammonia by compressing it and the total heat is used in evaporating the product. All of the vapour, in giving up its heat to the ammonia, is condensed and can be re-used if required. As a heat pump works on a reverse Carnot cycle, there is a gain of heat, that is to say, the heat output from the system is greater than the heat input, and for the temperatures normally encountered the heat gain is approximately 12, so that, theoretically, 12 times as much heat can be extracted from the system as is put into it.

Advantages claimed for the *Lo-Temp* are: (*a*) simplicity and economy of operation, which can be made fully automatic, (*b*) low evaporation temperature (40 to 100°F. as desired), (*c*) only nominal amount of water required (and this may be eliminated in many cases), (*d*) condensate is recovered, making this system suitable for distillation as well as evaporation and (*e*) scale problems eliminated and saving in space.

The *Lo-Temp* evaporator, now being manufactured by Mojonnier Bros. Co., is used for the concentration of liquids at a relatively low temperature and is therefore especially suitable for the concentration of heat-sensitive liquids. It can also be used for the low-temperature distillation and fractionation of solutions, with recovery of both solvent and concentrate and for the experimental distillation of flavour extracts and essences.

It is claimed that a greater amount of concentration is possible with a *Lo-Temp* than with steam evaporation, especially with milk, so that when spray-drying equipment is used the drying duty is reduced. This reduction is reflected in the decreased fuel consumption and in the lower-powered atomising pump, air fans, etc. It is also reflected in a decreased capital cost for the sprayer drier and in an overall lowered cost of operation brought about by shifting a part of the total load from high-cost spray drying to low-cost concentration.

These evaporators cover a wide range of evaporation duties; from the small 2-h.p. laboratory model with an evaporation duty of 10 to 45 lb./hr., depending on the viscosity of the product being concentrated, to a quadruple-effect evaporator with an evaporation rate of 30,000 lb./hr. **CPE 1066**

Flow regulator

A flow regulator introduced by Martonair Ltd. is of in-line construction and is claimed to be suitable for the speed control of pneumatic cylinders up to 40 cu.ft./min. of free air. The materials employed are brass and manganese bronze, and the maximum operating pressure is 150 p.s.i.

A feature of this ¼-in. B.S.P. regulator is the complex taper of the adjusting needle. Instead of the parabolic curve obtained by the occlusion of an orifice by a needle of simple taper, a curve is obtained giving approximately 40% increase in flow (and cylinder speed) per turn of the adjusting screw, thus combining precise regulation at low flows with high maximum flow.

It is hoped to introduce ½-in. B.S.P. versions of this regulator at an early date. **CPE 1067**